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BASELINE HUMAN HEALTH RISK ASSESSMENT FOR RECREATIONAL VISITORS AT RICHARDSON FLAT TAILINGS PARK CITY, SUMMIT COUNTY, UTAH

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Prepared for the:

United States Environmental Protection Agency
Region 8
999 18th Street, Suite 500
Denver, CO 80202

Prepared by:

Syracuse Research Corporation
Environmental Science Center - Denver
999 18th Street, Suite 1975
Denver, CO 80202

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EXECUTIVE SUMMARY

Site Description and Background

The Richardson Flats Tailing (RFT) Site is located 1.5 miles northeast of Park City, Utah occupying about 700 acres in a small valley in Summit County, Utah (Figure 1-1). The RFT site is part of the Park City Mining District where silver-laden ore was mined and milled from the Keetley Ontario Mine as well as other mining operations (RMC, 2001a). Tailings were deposited into an impoundment covering 160 acres of the 700 acre property just east of Silver Creek. Tailings were deposited to the impoundment from the mill by use of a slurry pipeline from 1975 through 1981. Mining and milling operations ended in 1982.

This document is a baseline human health risk assessment (BHHRA) for recreational users of the RFT site. The purpose of the document is to assess the health risks to visitors, from chemical contaminants in tailings and other environmental media present at this site. The results of this assessment are intended to help inform risk managers and the public about the level of health risk which is attributable to the contamination, to help determine the need for remedial action at the site, and to provide a basis for determining the levels of chemicals that can remain onsite and still be adequately protective of public health (USEPA 1989a).

Selection of Chemicals of Potential Concern

The Chemical of Potential Concern (COPC) were selected using a four step selection process as follows:

Step 1. Evaluation of Essential Nutrients
Step 2: Evaluation of Detection Frequencies
Step 3: Comparison with Background Concentrations
Step 4: Toxicity/Concentration Screen

Based on these steps, arsenic and lead were identified as COPCs and evaluated quantitatively in the site risk assessment.

Exposure Assessment

There are a wide variety of different recreational activities which people may engage in at this site, and hence there are a wide variety of different recreational exposure scenarios which might warrant evaluation. Two separate use scenarios were considered to serve as the representative populations evaluated:

- **low intensity users** such as, hikers, bikers, and picnickers
- **high intensity users** such as, horseback riders, ATV users, dirt-bikers, soccer and baseball players

The low intensity users were assumed to range in age from young children to adults, whereas the high intensity users were assumed to be an older (teenage to adult) population. The risk assessment is based on the assumption that no further remedial or construction activities will occur at the site. That is, the activities listed will be assumed to occur on current contaminated site conditions, rather than on baseball and/or soccer fields created using clean fill material, sod and turf.

There are a number of pathways by which these recreational visitors may come into contact with contaminants in site media. The following exposure scenarios were judged to be of sufficient potential concern to warrant quantitative exposure and risk analysis at this site:

Population	Pathway
Low Intensity User	-Ingestion of Soil/Tailings -Ingestion of Surface Water -Dermal Exposure to Surface Water -Ingestion of Sediment -Inhalation of Particulates in Air
High Intensity User	-Ingestion of Soil/Tailings -Inhalation of Particulates in Air

Quantification of Exposure and Risk from Non-Lead Contaminants

Methods

Risks to low- and high-intensity recreational visitors from exposure to arsenic in site media were evaluated according to standard USEPA methods.

All exposure and toxicity factors used for the varying exposure scenarios are presented in Chapter 5 of the risk assessment. The relative bioavailability of arsenic was assumed to be equal to the default value of 80% due to a lack of site-specific data.

Concentrations of Non-Lead COPCs

Because the true mean concentration of a chemical within an Exposure Point cannot be calculated with certainty from a limited set of measurements, the USEPA recommends that the upper 95th confidence limit (UCL) of the arithmetic mean concentration be used as the Exposure Point Concentration (EPC) in calculating exposure and risk (USEPA 1992a). If the calculated UCL is higher than the highest measured value, then the maximum value is used as the EPC instead of the UCL (USEPA 1992a). In accord with this policy, EPCs were calculated for arsenic in each of the media types at this site. These values are summarized below:

Media	EPC (ppm)
Sediment	198
Surface Water	0.014
Soil/Tailings	55.4
Air- High Intensity User	0.00000025
Air- Low Intensity User	0.00000004

Noncancer and Cancer Risks

Noncancer risks are described in terms of the ratio of the dose at the site divided by a dose that is believed to be safe. This ratio is referred to as the Hazard Quotient (HQ). If the HQ is equal to or less than a value of 1, it is believed that there is no appreciable risk that noncancer health effects will occur. If an HQ exceeds 1, there is some possibility that noncancer effects may occur, although an HQ above 1 does not indicate an effect will definitely occur. However, the larger the HQ value, the more likely it is that an adverse health effect may occur.

Arsenic is listed by EPA as an oral carcinogen. Risk of cancer from exposure to arsenic is described in terms of the probability that an exposed individual will develop cancer because of that exposure by age 70. The level of cancer risk that is of concern is a matter of individual, community and regulatory judgement. However, the USEPA typically considers risks below 1 in a million to be so small as to be negligible, and risks above 100 per million to be sufficiently large that some sort of action or intervention is usually needed.

Results

The following table present both cancer and non-cancer risks for exposure to arsenic by both low- and high-intensity recreational users. As seen, for both low- and high-intensity users the total risks are below a Hazard Index of 1.0 for both average and RME exposure assumptions. The majority of the predicted risk is primarily attributable to ingestion of soils/tailings. Excess cancer risks were not found to exceed 100 cases per million for either low- or high-intensity recreational users under either average or RME exposure scenarios.

Endpoint	Population	Average	RME
Non-Cancer	Total Risk Low Intensity User	0.024	0.093
	Total Risk High Intensity User	0.014	0.058
Cancer Risk (per million)	Total Risk Low Intensity User	1.8	22
	Total Risk High Intensity User	<1	11

Uncertainties

Several assumptions used in the evaluation of risks from non-lead COPCs at this site may introduce uncertainty into the presented findings. Although in most cases, assumptions employed in the risk assessment process to deal with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate rather than an underestimate of risk, it is nevertheless important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site.

Uncertainties presented in the risk assessment include: uncertainty in concentration estimates, uncertainty in human intakes, uncertainty in toxicity values, uncertainty in absorption from soil and uncertainty from pathways not evaluated.

Quantification of Exposure and Risk from Lead

Methods

Risks from lead are usually evaluated by estimation of the blood lead levels in exposed individuals and comparison of those blood lead values to an appropriate health-based guideline. In the case of lead exposure, the population of chief concern is young children (age 0-84 months), due to the type of health effects that occur in this age bracket. The USEPA and CDC have set as a goal that there should be no more than a 5% chance that a child should have a blood lead value over 10 ug/dL. For convenience, the probability of exceeding a blood lead value of 10 ug/dL is referred to as P10.

Blood lead levels in an exposed population of children may either be measured directly, or may be calculated using a mathematical model. Because no measured blood data were available, the modeling approach was utilized at this site. Both young children (less than 7 years of age) and adults were evaluated for exposure to lead in the low intensity recreational scenario. The modeling approaches used to evaluated these two distinct age groups are explained below. Under the high intensity scenario only exposure to teenagers and adults was evaluated.

IEUBK Model

The USEPA has developed an integrated exposure, uptake and biokinetic (IEUBK) model to assess the risks of lead exposure in residential children. This model requires as input point estimates of the average concentration of lead in various environmental media in residential properties at the site, and the average amount of these media contacted by a child living at the site. These data are used to estimate the average blood lead value in an exposed child. Then, a distribution of blood lead values is estimated by assuming a lognormal distribution and applying an estimated geometric standard deviation (GSD).

For this site, two simulations were run using the IEUBK model. The first evaluated risks to a hypothetical nearby resident. The second simulation was used to address the risk observed when the hypothetical residential child engaged in low-intensity recreational activities at the site. By comparing the two simulations and resulting predictions of blood lead concentrations, the excess risk attributable to the recreational exposure can be identified, in order to judge whether the risks to any random child participating in site-based recreational activities are within health based goals.

The resulting predictions of the IEUBK model for these two scenarios are shown below. As seen, children who engage in low intensity recreational activities at this site have higher predicted blood lead levels than those with no recreational exposure. However, the geometric mean values are relatively low and children engaging in recreational activities have under a 5% chance of exceeding a blood lead value of 10 ug/dL using a GSD value of either 1.4 or 1.6.

Scenario	GSD = 1.4		GSD = 1.6	
	Geometric Mean Blood Lead (ug/dL)	P10	Geometric Mean Blood Lead (ug/dL)	P10
Residential Only	1.9	0%	1.9	0.01%
Residential + Recreational	3.8	0.16%	3.8	1.76%

These results indicate that current risks to recreational child visitors from lead is likely to be well below EPA's health-based goal at this site.

Bower's Model

The risks to teenage and adult recreational visitors (low and high intensity) from exposure to lead in site media were evaluated using the Bower's model. This model predicts the blood lead level in an adult exposed to lead by summing the "baseline" blood lead level (PbB_0) (that which would occur in the absence of any above-average site-related exposures) with the increment in blood lead that is expected as a result of increased exposure due to contact with a lead-contaminated site medium. This model was run in accord with guidance developed by EPA's Technical Workgroup for Lead (USEPA, 1996).

For low intensity visitors, the geometric mean blood lead concentration was predicted to be 1.6 ug/dL with a PbB_{95} value of 4.3 ug/dL. For high intensity visitors, the geometric mean blood lead concentration was predicted to be 1.8 ug/dL with a PbB_{95} value of 4.8 ug/dL. The USEPA has not yet issued formal guidance on the blood lead level that is considered appropriate for protecting the health of pregnant women or other adults. Therefore, these results can be interpreted using a health criterion that there should be no more than a 5% chance that the blood level of a fetus will be above 10 ug/dL. This is equivalent to a blood lead concentration of 11.1 ug/dL in the pregnant adult. A comparison of the 95th percentile blood lead levels predicted for site recreational visitors shows that recreational use at this site is not predicted to result in blood lead levels which exceed a target concentration of 11.1 ug/dL under either low- or high-intensity use scenarios..

Uncertainties

Several assumptions used in the evaluation of lead risks at this site may introduce uncertainty into the presented findings. Although in most cases, assumptions employed in the risk assessment process to deal

with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate rather than an underestimate of risk, it is nevertheless important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site. Uncertainties presented in the risk assessment include: uncertainty in lead concentrations estimates, uncertainty in lead absorption from soil, and uncertainty in the modeling approach.

Conclusions

The results of risk calculations for arsenic presented in this report indicate that for all evaluated scenarios (low-intensity, high-intensity, CTE, RME) non-cancer risks are below a Hazard Index of 1.0. Additionally, all cancer risks were estimated to be within or below EPA's acceptable risk range of one in a million to one in 100,000.

Risks from lead exposure were evaluated at this site using both the IEUBK model (children) and the Bower's model (teenagers and adults). Both models resulted in predictions of blood lead levels that were below a 5% probability of exceeding a blood lead level of 10 ug/dL.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AF	Absorption Fraction
ASARCO	American Smelting and Refining Company
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	All-terrain Vehicle
BHHRA	Baseline Human Health Risk Assessment
BKSF	Biokinetic Slope Factor
BW	Body Weight
C	Concentration
CDC	Centers for Disease Control
CEPA	California Environmental Protection Agency
COPC	Contaminant of Potential Concern
CTE	Central Tendency Exposure
DI	Daily Intake
E&E	Ecology & Environment, Inc.
ED	Exposure Duration
EF	Exposure Frequency
HI	Hazard Index
HIF	Human Intake Factor
HQ	Hazard Quotient
HRS	Hazard Ranking System
IR	Ingestion Rate
IRIS	Integrated Risk Information System
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
NPL	National Priorities List
PbB	Blood Lead Concentration
PbS	Soil Lead Concentration
PCV	Park City Ventures
RBA	Relative Bioavailablity
RBC	Risk-based Concentration
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RFT	Richardson Flat Tailings
RI/FS	Remedial Investigation/Feasibility Study
RMC	Resource Management Consultants
RME	Reasonable Maximum Exposure
SERA	Screening Ecological Risk Assessment
SF	Slope Factor

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

STORET	EPA's Storage and Retrieval System
TAL	Target Analyte List
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TWA	Time-weighted Average
UCL	Upper Confidence Limit
UPCM	United Park City Mines
USEPA	United States Environmental Protection Agency
XRF	X-Ray Fluorescence
WOE	Weight of Evidence

1.0 INTRODUCTION

1.1 Site Description

The Richardson Flats Tailing (RFT) Site is located 1.5 miles northeast of Park City, Utah occupying about 700 acres in a small valley in Summit County, Utah (Figure 1-1). The RFT site is part of the Park City Mining District where silver-laden ore was mined and milled from the Keetley Ontario Mine as well as other mining operations (RMC, 2001a). Tailings were deposited into an impoundment covering 160 acres of the 700 acre property just east of Silver Creek. Tailings were deposited to the impoundment from the mill by use of a slurry pipeline from 1975 through 1981. Mining and milling operations ended in 1982. A detailed description of the site history is presented in Section 2.

1.2 Purpose and Scope

This document is a baseline human health risk assessment (BHHRA) for recreational users of the RFT site. The purpose of the document is to assess the health risks to visitors, from chemical contaminants in tailings and other environmental media present at this site. The results of this assessment are intended to help inform risk managers and the public about the level of health risk which is attributable to the contamination, to help determine the need for remedial action at the site, and to provide a basis for determining the levels of chemicals that can remain onsite and still be adequately protective of public health (USEPA 1989a).

The methods used to evaluate risks to humans and the environment employed in this assessment are consistent with current guidelines provided by the USEPA for use at Superfund sites (USEPA 1989a, 1991a, 1994).

1.2 Organization

In addition to this introduction, this report is organized into the following sections:

Section 2 This section provides the site characterization, which includes the site location, description, regulatory history, and environmental setting.

Section 3 This section provides a summary of the available data on the levels of chemical contaminants (metals) in site media, and identifies which of these chemicals are of potential health concern to area residents.

Section 4 This section discusses how visitors may be exposed to site-related chemicals, now or in the future, and identifies exposure scenarios that are considered to be of potential concern.

Section 5 This section assesses the level of exposure and risk to humans from non-lead chemicals of potential concern at this site. This includes 1) a description of methods used to quantify

exposure to these chemicals, 2) data on the toxicity of these chemicals to humans, 3) calculation of the level of noncancer and cancer risk that may occur as a result of exposure to these chemicals in site soils, and 4) a discussion of the uncertainties which limit confidence in the assessment.

Section 6 — This section assesses the level of exposure and risk to area visitors from lead in site soils. This includes 1) a description of the toxic effects of lead, 2) a summary of the method used by USEPA to evaluate risks from lead, 3) a summary of the estimated risks at this site attributable to lead in site soils, and 4) a discussion of the uncertainties which limit confidence in the assessment.

Section 7 — This section summarizes the overall findings presented in Sections 5 and 6.

Section 8 — This section provides full citations for USEPA guidance documents, site-specific studies, and scientific publications referenced in the risk assessment.

2.0 SITE CHARACTERIZATION

This section contains the location, description, regulatory history and environmental setting of the RFT Site. This information originated in the RFT Screening Ecological Risk Assessment (USEPA, 2002), but has been reiterated in this document for individuals who may not be familiar with the site background.

2.1 Site Location

As discussed in Section 1, the RFT Site is a 700 acre property located in a small valley in Summit County, approximately 1.5 miles northeast of Park City, Utah (Figure 1-1). This site is part of the larger Park City Mining District where silver-laden ore was mined and milled from the Keetley Ontario Mine as well as other mining operations (RMC, 2001a). Tailings from these operations were deposited onsite into an impoundment covering approximately 160 acres of RFT property. These tailings were deposited to the impoundment just east of Silver Creek mill by use of a slurry pipeline from 1975 through 1981. Mining and milling operations ended in 1982.

2.2 Site Description

Tailings were first placed on the RFT Site prior to 1950 (RMC, 2000a). Historical aerial photos confirm that tailings have been present at the flood plain tailings pile as early as 1953 (USEPA, 1991a). The mill tailings present consist mostly of sand-sized particles of carbonate rock with some minerals containing silver, lead, zinc and other metals. Few specific details are available concerning the configuration and operation of the historic tailings pond (prior to 1950) but certain elements are apparent. From time to time, tailings were transported to the Site through three distinct low areas on the southeast portion of the Site. Over the course of time, tailings materials settled out into the low areas that were ultimately left outside and south of the present impoundment area constructed in 1973 to 1974 (RMC, 2001b).

In 1970, Park City Ventures (PCV), a joint venture partnership between Anaconda Copper Company and American Smelting and Refining Company (ASARCO) entered into a lease agreement with United Park to use the Site for the disposal of additional mill tailings generated from renewed mining in the area. PCV contracted with Dames & Moore to provide construction specifications for reconstruction of the Site for continued use as a tailings impoundment (Dames & Moore, 1974). The state of Utah approved the Dames & Moore plan and the current impoundment area was constructed in 1974 (RMC, 2000a). Before disposing of tailings on the Site, PCV installed a large earthen embankment along the western edge of the existing tailings impoundment and constructed perimeter containment dike structures along the southern and eastern borders of the impoundment to allow storage of additional tailings. PCV also installed a diversion ditch system along the higher slopes north of the impoundment and outside of the containment dike along the east and south perimeter of the impoundment to prevent surface runoff from surrounding land from entering the impoundment (RMC, 2001b). Dames & Moore recommended that specially engineered seepage control devices be installed at the base of the main embankment. PCV did not follow this recommendation (Dames & Moore, 1974).

PCV conveyed tailings to the impoundment by a slurry pipeline from its mill facility located south of the Site. Over the course of operation, approximately 420,000 tons of tailings were disposed of at the Site. PCV failed to follow recommendations for disposal of the slurry in the impoundment (to place tailings along the perimeter of the impoundment and move towards the center) and placed a large volume of tailings near the center of the impoundment in a large, high-profile, cone-shaped feature. After cessation of operations in

1982, the presence of the cone-shaped feature resulted in prevailing winds form cutting into the tailings and the tailings becoming wind-borne (RMC, 2001b).

The RFT Site is currently under the ownership of United Park City Mines (UPCM) (RMC, 2000a). UPCM is a consolidation of Silver King Coalition Mines Company and Park Utah Consolidated Mines Company, formed in 1953 (RMC, 2000a).

2.2.1 Sources

There are two known sources of contamination at the RFT Site. These include the tailings impoundment previously described and a flood plain tailings pile. The flood plains tailings pile is located immediately west of the tailings impoundment and covers about 6 acres along the banks of Silver Creek (USEPA, 1991a). This source is reported to be located on the western side of Silver Creek about 300 feet upstream of the confluence of Silver Creek with the wetland area and extends from there for about 2,500 feet upstream. The USEPA and the State of Utah have both observed tailings entering Silver Creek from the flood plain tailings pile (USEPA, 1991a). According to analyses performed in 1985 and 1989, the flood plain tailings pile contains arsenic, cadmium, copper, lead, mercury, silver, and zinc (USEPA, 1991a).

2.2.2 Site Features

The Focused Remedial Investigation/Feasibility Study (RI/FS) Workplan prepared by RMC in May 2000, provides detailed information on the RFT Site features. Information pertaining to the main embankment and containment dikes, the diversion ditches and off-impoundment tailings is summarized in the following subsections.

2.2.2.1 Main Embankment and Containment Dikes

The majority of the tailings at the RFT Site are contained in a closed basin, with a large, earth, embankment in place along the western edge of the Site. The "main embankment" is vegetated and is approximately 40 feet wide at the top, 800 feet long, and has a maximum height of 25 feet. This embankment is designed to allow water to seep from the impoundment to relieve hydraulic pressure on the embankment. Currently, surface water is present in the form of a seep located near the north end of the base. A series of man-made containment dikes contain the tailings along the southern and eastern perimeter of the impoundment. The northern edge of the impoundment is naturally higher than the perimeter dikes (RMC, 2000a).

2.2.2.2 Diversion Ditches

A diversion ditch system borders the north, south, and east sides of the impoundment to prevent runoff from the surrounding land from entering the impoundment. Precipitation falling on the impoundment area creates a limited volume of seasonal surface water. The north diversion ditch collects snowmelt and storm water runoff from upslope, undisturbed areas north of the impoundment and carries it in an easterly direction towards origin of the south diversion ditch. An unnamed ephemeral drainage to the southeast of the impoundment also enters the south diversion ditch at this point. Additional water from spring snowmelt and storm water runoff enters the south diversion ditch from other areas lying south of the impoundment at a point near the southeast corner of the diversion ditch structure. Water in the south diversion ditch flows from east to west and ultimately empties into Silver Creek just upstream of Highway 189 near the north border of the Site. Water flow from the south diversion ditch into Silver Creek occurs during the higher water periods of the year (RMC, 2000a).

2.2.2.3 Off-Impoundment Tailings

Additional tailings materials are present outside and to the south of the current impoundment area. During historic operations of the tailings pond, tailings accumulated in three naturally low areas adjacent to the property that eventually became the impoundment. In the 1970s, when PCV constructed the perimeter dike and diversion ditch along the south perimeter of the impoundment, tailings present in the three low areas were left in place, outside of the present impoundment. Starting in 1983, United Park reportedly covered most of these tailings outside of the current impoundment with a low permeability, vegetated soil cover. Other types of clean fill material, imported from construction work in Park City, were also used to cover the tailings outside of the impoundment. The cover in some of these areas is reported to be as thick as 10 to 15 feet (RMC, 2000a). However, recent surveys of off-impoundment cover soils indicate that at some locations soil cover is absent leaving exposed surface tailings and in other places the soil cover is less than a few inches (RMC, 2001a).

2.2.3 Site Activities

UPCM and others have conducted certain efforts at the RFT Site to support investigation of integrity or closure. These activities are briefly described in the following subsections.

2.2.3.1 Impoundment Integrity Analyses

Noranda Mining, Inc. (Noranda) leased the RFT Property from UPCM in 1980 (RMC, 2000a). Shortly after Noranda entered into the lease agreement, Dames & Moore was contracted to conduct an impoundment integrity investigation. Although several construction flaws are noted, including the oversteeping of the main embankment along various locations, Dames & Moore concludes that the main embankment and containment dikes are in no immediate threat of failure. Dames & Moore once again recommends the installation of seUSEPAge control systems at the base of the main embankment (RMC, 2000a). Noranda does not follow this recommendation. Noranda disposed of 70,000 tons of additional tailings material and ceased operations in 1982. No new tailings have been placed at the Site since that time (RMC, 2000a).

2.2.3.2 Soil Cover of Tailings

Starting in 1983, UPCM began placing soil cover on tailings outside of the impoundment, located in three low areas south of the south diversion ditch (Figure 2-1). By 1985, the tailings impoundment had dried out enough in certain areas to support heavy equipment and UPCM began installing soil cover material over those portions. The cover soils are reported to be clay-rich and came from both the Park City area and from within the RFT Site (RMC, 2000a).

Between 1985 and 1988, UPCM also placed soil cover around the cone shaped tailings structure inside the impoundment area at locations where it had dried out enough to support heavy equipment. The primary objective of placing the soil cover was to prevent prevailing winds from cutting into the cone-shaped tailings By 1988, this work was completed and UPCM began a more aggressive program to cover all exposed tailings. It is reported that at least 12 inches of low-permeability, clay cover material was placed in the impoundment and that the soil cover was then vegetated (RMC, 2000a). More recent inspection of the cover soils at the main impoundment and off-impoundment indicate a shallow soil cover in some areas (less than 12 inches) and no soil cover in other locations (RMC, 2001a).

By 1992, repairs to soil cover work were completed (RMC, 2000a). Shortly after completion, E&E (1993) completed a soil depth survey within the impoundment and an inspection of the main embankment. X-Ray Fluorescence (XRF) was used to confirm the visual contrast between top soil and the tailings below (E&E, 1993). E&E (1993) determined that on average, cover soils varied between less than 6 inches and 14 inches in depth. Areas in which cover soils were known to be more than 3 feet in depth were not surveyed. For the 29 locations studied, one exhibited exposed tailings. As a result, UPCM placed additional soil in this area (RMC, 2000a). More recent soil cover surveys for the main impoundment, however, indicate that at some locations the soil cover is less than 12 inches in depth (RMC, 2001a; 2001b).

2.2.2.3 Wedge Buttress Reinforcement

In an effort to correct the over-steepened portions of the main embankment, UPCM proposes to design the installation of a wedge buttress. The buttress will enhance the long-term effectiveness of the final closure remedy for the Site. UPCM will evaluate the condition of the main embankment during the RI/FS, and then prepare construction design specifications as part of the final remedial design process. Data from the seep located at the base of the main embankment may need to be gathered in order to develop an appropriate wedge buttress design (RMC, 2000a).

2.2.2.4 Fencing

In the mid 1980's, UPCM installed a fence along most of the Site boundary, including the entire impoundment and much of the property south of the impoundment. The fence was placed to restrict access to the Site. UPCM reports it will maintain the fence in good repair and will continue to control site access until such time limited access is no longer necessary (RMC, 2000a).

2.2.2.5 Diversion Ditch Reconstruction

In 1992 and 1993, UPCM reconstructed the south diversion ditch by decreasing the slope of its banks from nearly vertical to a more gradual slope. UPCM placed a clay soil cover over the re-sloped banks down to and including areas of the banks underwater. The existing ditch banks were re-vegetated and the bottom of the ditch was not disturbed during these efforts. In May of 1999, United Park reconstructed the north diversion ditch along its entire length in the same manner (RMC, 2000a).

2.3 Regulatory History

The RFT Site was first proposed for the National Priorities List (NPL) on June 24, 1988. The original Hazard Ranking System (HRS) score of 50.23 was based on surface water and air migration pathways (USEPA, 1991a). Areas evaluated in the HRS included the impoundment and adjacent areas (USEPA, 1991a). Based on public comments, the site was dropped from consideration for the NPL on February 11, 1991 (USEPA, 1991a). The HRS scoring criteria for surface water migration pathways were revised in 1992. The USEPA is currently proposing the site for a second NPL consideration under the revised HRS (USEPA, 1991a). Along with the impoundment area and adjacent areas, the new proposal includes the Park City Municipal Landfill and the Silver Creek flood plain area (RMC, 2000a).

2.4 Site Environmental Setting

2.4.1 Topography and Surrounding Land Use

The site is located in a rural area whose topography is characterized by a broad valley with undeveloped rangeland. Silver Creek is located within a few hundred feet from the main tailings impoundment. This perennial stream drains other historic tailing ponds in the Park City area (Mason, 1989). Silver Creek originates in an upper mountain zone where access is limited to recreational users. As Silver Creek passes through Park City and in to the surrounding suburban areas, the land use is primarily residential and commercial, changing to recreational and agricultural downstream to its confluence with the Weber River (RMC, 2001a).

2.4.2 Geology and Hydrogeology

2.4.2.1 Geology

The RFT Site is located in the Wasatch Range Section of the Middle Rocky Mountain Physiographic Province in north-central Utah in an area composed of a complex fold and thrust belt that is covered over with igneous rock (RMC, 2000a; 2000b). The sedimentary bedrock, which dates to the Paleozoic and Mesozoic age, is covered by a thick layer of extruded igneous rock that dips approximately 25 to 60 degrees to the north and strikes northeast-southwest (Bromfield and Crittenden, 1971). Tertiary gravels and igneous rocks cover the Mesozoic sedimentary rocks (RMC, 2001a). There are no known faults near the RFT Site.

Alluvial and colluvial sediments lie 30 to 50 feet deep beneath the tailings on site. These sediments are a product of the erosion of neighboring and underlying igneous extrusions. Borehole data have shown that these sediments consist of: 2-5 feet of soft, organic, and clay rich topsoil; 1-30 feet of mixed fine-grained silt and clay; 4 feet of sand and gravel; highly weather, volcanic breccia which is composed of soft, tight, sandy and silty clay grading to harder fractured volcanic rock (RMC, 2000b). The unconsolidated valley fill is reported to range in thickness from a few feet adjacent to hills and mountains to at least 260 feet, centrally in valleys (Mason, 1989)

2.4.2.2 Hydrogeology

In 1999, UPCM contracted Weston Engineering, Inc. (Weston) to conduct a hydogeological survey of the site. The hydrogeology in the area consists of shallow alluvial aquifers located in the alluvial and colluvial material as well as the deeper Silver Creek Breccia bedrock aquifer located in the Keetley volcanics (RMC, 2000b). The shallow aquifers are found fifteen to thirty feet below the ground surface in gravelly clay. The shallow aquifers' hydraulic gradients parallel topography (south to north) except at the southern boundary of the tailings embankment where flow changes to the northwest due to diversion ditches. The hydrogeology of the Site area has been described in a separate report (Weston, 1999).

2.4.2.3 Hydrology

Silver Creek flows approximately 500 feet from the main embankment along the west edge of the Site (RMC, 2000a). The headwaters of Silver Creek are comprised of three major drainages in the Upper Silver Creek Watershed; the Ontario Canyon, the Empire Canyon and Deer Valley. Flows from Ontario and Empire Canyons occur in the late spring to early summer months in response to snowmelt and rainfall, while Deer Valley flows appear to be perennial and originate from snowmelt and springs (RMC, 2000b). Surface water

runoffs for this watershed are lower than those of comparable mountain watersheds which are less fractured and may have a more developed layer of unconsolidated materials (Brooks et al., 1998). Overall, runoff and precipitation flows from Empire and Ontario Canyons are low compared to the substantially large flow contributed by Deer Valley (USEPA, 2001a). The major influence on water flow in Silver Creek near the RFT Site is the Pace-Homer (Dority Springs) Ditch, which derives most of its flow from groundwater (USEPA, 2001a). The outflow from the Pace-Homer Ditch enters Silver Creek at several locations across the Prospector Square area. Significant riparian zones and wetlands exist near the RFT Site in areas that historically consisted of accumulated tailings piles.

2.4.3 Climate

Richardson Flat is located in north-central Utah. The average monthly precipitation is approximately 3.64 inches with an average annual precipitation of 43.68 inches (www.weather.com - accessed 08/5/01). The average monthly temperature ranges from 19°F to 58°F. with an average for the year of 36°F. Elevations near the RFT Site range from 6,930 to 9,075 feet above sea level (RMC, 2000b).

3.0 DATA SUMMARY AND EVALUATION

The BHHRA is based on the available analytical and physical data from investigations completed within the RFT Site area. A summary of the raw data is provided as Appendix A. These results represent the known nature and extent of contamination and are used as the basis of the BHHRA. The BHHRA is based only on analytical data from within or adjacent to the site. The study area boundary is shown in Figure 3-1.

3.1 Tailings Data

As previously discussed, contamination at the RFT Site originated from the deposition of tailings within and outside of an impoundment. In July 1989, one tailings sample from the main impoundment area (stratified depths from 1-18 inches) and five tailings samples (0-6 inches) from flood plain areas were collected and data were presented in the Hazard Ranking System (USEPA, 1991a). These samples were analyzed for total arsenic, cadmium, copper, lead, mercury, silver and zinc.

In May 2001, RMC collected tailings samples from the three locations within the impoundment at 1 foot depth intervals (beginning from the bottom of the cover soils to a depth of 5 feet). Samples were analyzed for aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, selenium, silver, and zinc. These samples were collected to evaluate the long-term fate of metals in tailings and the chemical stability of the tailings (RMC, 2001a).

Tailings disposal is also present in areas located outside the impoundment, but the spatial extent of these areas are not well defined. In June 2001, RMC collected tailings samples from locations south of the south diversion ditch in an effort to determine the extent of tailings disposal. This study was also completed to evaluate soil cover thickness, and if the tailings were contributing to zinc concentrations in the south diversion ditch. Samples were analyzed for aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, selenium, silver, and zinc.

3.2 Soils Data

3.2.1 On-Impoundment Soils

In August 1992, Ecology & Environment, Inc. (E&E), under direction from USEPA, investigated the RFT Site with respect to immediate threats to human health or the environment. The depth of soil cover was determined at 29 locations on the impoundment (based on an approximate grid pattern of 400 ft by 400 ft). At six of these locations, samples were analyzed for Target Analyte List (TAL) metals. Each of the samples, with the exception of sample RF-SO-3, are representative of cover soils on the impoundment in 1992. Sample RF-SO-3, was collected in an area of salt grass not yet covered by UPCM and is representative of tailings (E&E, 1993). Subsequently, UPCM placed additional soil cover in areas with thin cover (as identified by E&E, 1993) and on other areas to support site closure efforts (RMC, 2001a).

Currently, the cone-shaped tailings impoundment is reported to be covered with soil and vegetation with no areas of exposed tailings (RMC, 2001a). However, the extent, thickness, and chemical characteristics of the cover soils are not well defined. In May 2001, RMC collected 41 cover soils from 6 transects based on a 500 ft by 500 ft grid across the impoundment at a depth of 0-2 inches (distinct locations are identified as A through I). Additional depth samples, ranging from 5 to 18 inches, were collected at 11 of these locations. All samples were analyzed for arsenic and lead with 20% of the samples analyzed for all RCRA metals.

3.2.2 Background Soils

In order to determine the concentrations of metals in areas not affected by wind-blown tailings from the RFT Site, RMC collected background samples from areas not impacted by tailings deposition. It is important to note that these samples are representative of anthropogenic, non-site related levels, and do not represent "pristine" (not influenced by human activity) environmental levels. Therefore, these samples were not utilized in the BHHRA.

3.3 Surface Water Data

Surface water data were compiled from five sources including E&E (1993), Utah water quality monitoring, USEPA (2001), UPCM surface water monitoring, and RMC monthly sampling . A description of the surface water data from each source is provided in the following subsections.

For the purposes of conducting the BHHRA, surface water data from Silver Creek were limited to those stations adjacent to the RFT site boundaries. Upstream/downstream locations were excluded from further evaluation. Water data for the south diversion ditch are limited to samples collected after ditch reconstruction (1993 to present).

Ecology & Environment, Inc. (1993)

In August 1992, E&E collected surface water samples from Silver Creek and the south diversion ditch. Six samples were collected along Silver Creek (RF-SW-1 to RF-SW-6) and two samples were collected from the south diversion ditch (RF-SW-7 and RF-SW-8). On-site and adjacent samples included in this assessment were RF-SW-3, 4, 5, 7 and 8.

Utah Water Quality Monitoring (STORET)

Water quality monitoring data for several stations along Silver Creek were obtained electronically from an USEPA STORET download query (Modernized Version). Data is available from nine locations on Silver Creek of which one is located adjacent to the RFT site. Samples are collected and analyzed monthly for water quality parameters such as total hardness, pH, and temperature, as well as total recoverable and dissolved metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Information for the Silver Creek station located adjacent to the RFT site is provided in the following text table.

Station ID	Location Description	Latitude	Longitude	Sampling Dates
492685	Silver Creek at US40 Crossing east of Park City	40.683000	-111.456000	02-May-75 to17-Jun-99

USEPA (2001a) Silver Creek Watershed Sampling

In 2000, USEPA completed an investigation of the Silver Creek watershed to better characterize the sources of heavy metals and to evaluate the total maximum daily load (TMDL). A total of 31 surface water sampling locations are available from the watershed study for Silver Creek and its headwaters in Empire Canyon, Ontario Canyon, Deer Valley. For the purposes of the BHHRA only data from locations on or adjacent to the site are used for the risk evaluation. Surface water samples for USC-3 and USC-4 were collected from the south diversion ditch on the RFT Site. Samples were collected in May and September 2000, respectively, to account for high (peak spring runoff) and low flow (fall or winter seasons).

UPCM Monitoring

Since 1975, UPCM has collected surface water samples from the south diversion ditch (N5), and Silver Creek upstream (N4) and downstream (N6) of the confluence with the south diversion ditch. Surface water samples were collected monthly (usually from April to November) and analyzed for copper, cyanide, lead, mercury, manganese, zinc, total suspended solids (TSS) and total dissolved solids (TDS). At the time of the BHHRA, surface water data collected prior to April 1982 was not available for review.

RMC Monthly Sampling (RMC, 2001c)

Since May 1999, RMC has collected monthly surface water from several locations along Silver Creek, the south diversion ditch, the unnamed drainages flowing into the south diversion ditch, and ponded areas at the RFT Site. Specific locations are identified in and detailed station information is summarized in the following text table. Surface water samples were analyzed for total recoverable and dissolved TAL metals and water quality parameters.

Station ID	Location Description	Sampling Dates
RF-2	South diversion ditch	19-May-99 to 7-May-01
RF-3	Unnamed drainage flowing into the south diversion ditch	19-May-99 only
RF-3-2	Unnamed drainage flowing into the south diversion ditch	4-Apr-01 to 5-Jun-01
RF-4	South diversion ditch	19-May-99 to 9-Jul-01
RF-5	South diversion ditch	19-May-99 to 7-Aug-01
RF-6	South diversion ditch	19-May-99 to 18-Sep-00
RF-6-2	South diversion ditch	9-Jun-99 to 3-Dec-01
RF-7	Silver Creek upstream of confluence with south diversion ditch	19-May-99 to 7-Nov-00
RF-7-2	Silver Creek upstream of confluence with south diversion ditch	9-Jun-99 to 3-Dec-01
RF-8	Silver Creek downstream of the confluence with south diversion ditch	19-May-99 to 3-Dec-01
RF-9	Ponded water on the tailings impoundment	19-May-99 only
RF-10	Unnamed drainage flowing into south diversion ditch	9-Jun-99 only

3.4 Sediment Data

Sediment data are compiled for the BHHRA from three separate sources including E&E (1993), USEPA (2001) and RMC monthly sampling.

Use of surface water data for the south diversion ditch in the BHHRA is limited to samples collected after ditch bank modification. This limitation is not, however, placed on the use of sediment data. During reconstruction, UPCM did not disturb the bottom of the ditch bed (RMC, 2001a) thus the existing sediments were not disturbed and constraining use of the data set is not necessary.

As with the surface water data set, only Silver Creek sediments collected adjacent to the site were utilized in the risk assessment.

Ecology & Environment, Inc. (1993)

In August 1992, E&E collected four sediment samples (RF-SD-01 to RF-SD-04) from the south diversion ditch "wetlands" area located at the base of the main embankment and Silver Creek. Water flow through this wetlands area is primarily from the south diversion ditch, although some seepage from the impoundment area may influence the flow and chemistry (E&E, 1993). Based on the ratios of chemicals in tailings compared to those in the wetlands sediments, E&E concluded that the sediments in the wetlands area are tailings material from the impoundment (E&E, 1993).

USEPA (2001a) Watershed Sampling

USEPA collected sediment samples from 16 locations in the Silver Creek watershed. These samples were staggered across the watershed and co-located with specific surface water sampling sites to determine the relative level of metals throughout the system and evaluate interactions with surface water (USEPA, 2001a). At each location, both a surface and sub-surface (0-12 inches) sample was collected and analyzed for heavy metals. Because the BHHRA was limited to on-site and adjacent sampling locations, none of these analyses were included in this assessment.

RMC Monthly Sampling (RMC, 2001c)

In May 2001, RMC sampled sediments at six locations (RF-SD-1 to RF-SD-6) along the length of the south diversion ditch at a depth of 0 to 6 inches. These samples were collected to evaluate the long-term effectiveness of the wetland system to remove metals in the water and to aid in the determination of the source of metals in water flowing from the diversion ditch (RMC, 2001a).

3.5 Seep Data

Because the main embankment is designed to allow water to seep from the impoundment to relieve hydraulic pressure, it is likely that metals leach from tailings into groundwater at the RFT Site. At the RFT Site, a small seep (flow of gallons per day) is located at the northern base of the main embankment (RMC, 2000a). Currently, no water or sediment data exist for this seep.

3.6 Groundwater Data

Since 1973, PCV and UPCM have collecting groundwater data quarterly from monitoring wells MW-1, MW-2, and MW-3 (RMC, 2000a). After their installation in 1976, PCV also began collecting groundwater from wells MW-4, MW-5, MW-6. E&E began collecting additional groundwater data in 1984 from a well (RT-1) installed up gradient of the main embankment. E&E also sampled the two existing down gradient monitoring wells MW-1 and either MW-5 or MW-6 . [It is unclear as to which well, MW-5 or MW-6, was sampled.] Well MW-2 was buried during the installation of wells MW-4, MW-5, MW-6 in 1976. The USEPA contracted E&E in 1992 to collect ground water samples from three additional locations (RF-GW-04, RF-GW-05, and RF-GW-09). Consumption of groundwater is not a complete pathway for the recreational visitors at this site, therefore these data were not utilized in this assessment.

3.7 Air Data

In July 1986 air monitoring at RFT documented airborne releases of arsenic, cadmium, lead, and zinc. However, since that time a soil cover was placed over the tailings area, and subsequent air monitoring (June 1992) detected only zinc at low concentrations (0.1 ug/m^3) at three of the monitors (E&E 1993). The other chemicals were reported as non-detects with an unspecified detection limit. Therefore, due to the lack of quantitative values, these data were judged not useable for purposes of the risk assessment. Therefore, in assessing human health risks, the air concentrations were modeled.

3.8 Biological Tissue Data

At the time of the BHHRA, the analyses of contaminant concentrations in biological tissues (aquatic or terrestrial) were not available from existing data reports and literature.

3.9 Summary of Analytical Data

Table 3-1 provides a summary of the analytical data available for the BHHRA. This table compares the analytical parameters available for the environmental media sampled and analyzed. As previously described, there are eight sources of sampling data including: RMC (2000a), USEPA (1991); E&E (1993); USEPA (2001); RMC(2001a); RMC (2001c); UPCM and STORET. These programs do not have one common list of analytes for all environmental media. Table 3-1 provides a side-by-side comparison of the parameters available for each media type from each source of sampling data. Summary statistics for the data used in this assessment are provided in Table 3-2.

3.10 Selection of COPCs

Step 1. Evaluation of Essential Nutrients

In accord with USEPA guidance (1989a, 1994), chemicals that are normal constituents of the body and the diet and are required for good health may be eliminated unless there is evidence that site-specific releases have elevated concentrations in a range where intakes would be potentially toxic. Of the chemicals analyzed in soils and water at this site, 14 are classified as essential nutrients (calcium, cobalt, chloride, chromium, copper, fluoride, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, and zinc). Therefore, the assumed recreational intakes of these 14 constituents in site media were compared to their corresponding toxicity value or safe nutritive level as provided in USEPA 1994. The parameters used to calculate the recreational intake values are presented in Appendix B. These values were then multiplied by the maximum detected concentration of a chemical in each media to obtain a daily intake for that chemical. This intake was then divided by the screening value provided by USEPA (1994) to determine if the chemical could be eliminated from further analysis based on an observed ratio of less than 1.0 (i.e., predicted intake does not exceed safe level).

Results are summarized in Table 3-3. As shown, all of the beneficial chemicals analyzed in sediments and surface water can be eliminated from further evaluation. For soil and tailings, only four beneficial chemicals were analyzed. All four (Chromium III, Copper, Selenium, Zinc) are below safe levels and can also be eliminated as potential COPCs.

Step 2: Evaluation of Detection Frequencies

A contaminant with a detection frequency of ≥5% is carried through the toxicity/concentration screening process (Step 3). Chemicals having detection frequencies of <5% are usually assumed to be non-site related and are generally not evaluated as COPCs. However, it is important to ensure that the detection limit for such chemicals would have been adequate to detect the chemical if it were present at levels of human health concern. In sediments all chemicals analyzed were detected at frequencies greater than 5% and all of the detection limits were deemed adequate. Of the chemicals analyzed in surface water, three were observed with a detection frequency below 5%: silver, thallium, vanadium. Table 3-4 shows that the detection limits for these chemicals were adequate for risk assessment purposes. Thus, silver, thallium, and vanadium were eliminated as COPCs in surface water. In soil and tailings, no chemicals were observed to have a detection frequency of less than 5%. Therefore, All of the chemicals will be carried through for further evaluation as COPCs.

Step 3: Comparison with Background Concentrations

Concentrations of analyzed metals in site soils and tailings were compared to their published background ranges (Dragun, 1988; Shacklette and Boerngen, 1984; ATSDR). This comparison is presented in Table 3-5. As shown, both the average and maximum concentration of barium fall squarely within the ranges reported for the United States. Therefore, it was eliminated from further analysis as a COPC at this site. The other chemicals (arsenic, cadmium, lead, and mercury) were either clearly higher or not obviously within the reported background levels, and were carried further through the COPC selection process.

Step 4: Toxicity/Concentration Screen

The final step used to evaluate COPCs at this site was a toxicity/concentration screen conducted in accord with USEPA (1994) guidance. This step involves comparing the maximum reported concentration of a chemical in a medium to an appropriate Risk-Based Concentration (RBC). RBCs are media-specific health-based levels which if exceeded, could indicate that there is a potential for adverse health effects to occur as a result of exposure. If the maximum concentration value is less than the RBC, the chemical does not pose an unacceptable health risk and can be eliminated as a COPC. [Note: This is true providing that the chemical does not exceed any relevant ARAR values.]

The RBCs used in this evaluation were calculated using intake parameters associated with recreational visitors. Further details of these calculations are presented in Appendix B. RBC's were calculated for water, sediment, and soil/tailings. The value of each RBC depends on the specified Target Risk level. In accord with the goal that the COPC selection process should be conservative, the Target Risk levels used in this evaluation are 1E-06 for carcinogenic chemicals and a hazard quotient (HQ) of 0.1 for noncarcinogenic chemicals.

Table 3-6 lists the maximum concentration and RBC values used to evaluate each chemical in sediment, surface water, and soil/tailings and identifies those chemicals which were not eliminated from further consideration at this step.

Summary

The COPC screening process identified arsenic and lead for further quantitative evaluation in the risk assessment at this site.

4.0 EXPOSURE ASSESSMENT

Exposure is the process by which humans come into contact with chemicals in the environment. In general, humans can be exposed to chemicals in a variety of environmental media (e.g., soil, dust, water, air, food), and these exposures can occur through one or more of several pathways (ingestion, dermal contact, inhalation). Section 4.2 provides a discussion of possible pathways by which recreational users might come into contact with contaminants present in site media. Sections 5 and 6 describe the basic methods used to estimate the amount of chemical exposure (non-lead and lead) which humans may receive from direct and indirect contact with contaminants derived from outdoor soil.

4.1 Conceptual Site Model

Figure 4-1 presents a generalized conceptual site model showing the main pathways by which contaminants from current or former mining activities and other sources might come into contact with people exposed within the RFT site boundary. Exposure scenarios that are considered most likely to be of concern are shown in Figure 4-1 by a solid circle, while pathways which are judged to contribute only minor exposures are shown by a cross-hatched circle. Incomplete pathways (i.e., those which are not thought to occur) are shown by open circles.

4.1.1 Potential Sources

As discussed in Section 2, there are two known sources of contamination at the RFT Site. These include the primary onsite tailings impoundment and a flood plain tailings pile.

4.1.2 Migration Pathways

The current medium of chief concern is soil and tailings materials. Metals in these materials tend to have relatively low mobility and are most likely to move by wind-blown transport of suspended particles in air, surface run-off from nearby piles, or by hauling of bulk material from one location to another.

4.1.3 Exposed Populations and Potential Exposure Scenarios

Land use at this site is limited to recreational purposes. It is not envisioned, for the purposes of the human health risk assessment, that this property will be developed for residential purposes.

There are a wide variety of different recreational activities which people may engage in at this site, and hence there are a wide variety of different recreational exposure scenarios which might warrant evaluation. Two separate use scenarios were considered to serve as the representative populations evaluated:

- low intensity users such as, hikers, bikers, and picnickers
- high intensity users such as, horseback riders, ATV users, dirt-bikers, soccer and baseball players

The risk assessment is based on the assumption that no further remedial or construction activities will occur at the site. That is, the activities listed will be assumed to occur on current contaminated site conditions, rather than on baseball and/or soccer fields created using clean fill material, sod and turf.

4.2 Pathway Screening

4.2.1 Recreational Exposure - Low Intensity Users

Several pathways of exposure were reviewed for the low intensity recreational user. The low intensity user is an individual who visits the site for the purposes of activities such as hiking, biking, picnicking. It is thought that on occasion these visitors may also engage in activities at surface water locations, such as wading and splashing. The exposure pathways identified for these low intensity users are discussed in more detail below.

Incidental Ingestion of Soil/Tailings

Few people intentionally ingest soil. However, it is believed that most people (especially children) do ingest small amounts of soil that adhere to the hands or other objects placed in the mouth. This exposure pathway is often one of the most important routes of human intake, so it was selected for quantitative evaluation.

Dermal Contact with Soil

Visitors can get contaminated soil on their skin while engaging in recreational activities at the site. Even though information is limited on the rate and extent of dermal absorption of metals in soil across the skin, most scientists consider that this pathway is likely to be minor in comparison to the amount of exposure that occurs by soil and dust ingestion. This view is based on the following concepts: 1) most people do not have extensive and frequent direct contact with soil, 2) most metals tend to bind to soils, reducing the likelihood that they would dissociate from the soil and cross the skin, and 3) ionic species such as metals have a relatively low tendency to cross the skin even when contact does occur. Screening calculations (presented in Appendix C) support the conclusion that dermal absorption of metals from dermal contact with soil is likely to be relatively minor compared to the oral pathway, and omission of this pathway is not likely to lead to a substantial underestimate of exposure or risk. Based on these considerations, along with a lack of data to allow reliable estimation of dermal uptake of metals from soil, Region 8 generally recommends that dermal exposure to metals in soils not be evaluated quantitatively (USEPA 1995). Therefore, this pathway was not evaluated quantitatively in this risk assessment.

Inhalation of Soil/Tailings in Air

Particles of contaminated soil or dust become resuspended in air, and visitors may breathe those particles while engaged in activities at the site. Therefore, this pathway was selected for further quantitative evaluation.

Ingestion of Site Biota

Silver Creek is a potential location for fishing, and anglers who catch fish from reaches with significant water and/or sediment contamination may be exposed via ingestion of the fish. Similarly, hunters who harvest game animals (deer, waterfowl, etc.) from locations with significant contaminant levels in soil, vegetation or water may be exposed via ingestion of the game. Although it is considered plausible that this pathway might contribute a significant fraction of the total exposure, especially for individuals who rely on local fish or game as a main component of their diet, no data are available on contaminant levels in these media. Therefore, this pathway was not evaluated.

Ingestion of Surface Water

In warm weather, Silver Creek is a potential location for recreational activities such as wading and splashing. Although it is not expected that recreational visitors intentionally drink water from the river, these activities can lead to incidental ingestion of water, so this pathway was selected for quantitative evaluation.

Dermal Contact with Surface Water

Recreational visitors to the site may wade in the water at Silver Creek or in onsite wetlands areas, so dermal contact with surface water is likely (at least during warm weather). Therefore, the dermal exposure pathway for recreational visitors was evaluated quantitatively.

Contact with Sediments

People who enter the river or recreate in the onsite wetlands or drainage ditch areas may come into contact with sediments in the river bed, and exposure could presumably occur either by incidental ingestion and/or by dermal contact. However, because contact with sediments is associated with being in a water source, any material that gets on the hands or skin is likely to be largely washed off by the water. Therefore, dermal exposure to sediments was not evaluated quantitatively, however, incidental ingestion of these sediments was retained as a quantitative pathway of concern.

4.2.2 Recreational Exposure - High Intensity Users

Several pathways of exposure were reviewed for the high intensity recreational user. The high intensity user is an individual who visits the site for the purposes of activities such as horseback riding, dirt-bike and ATV riding, and playing soccer and/or baseball. It is thought that this group of recreational visitors is likely to have more intensive contact with site soils than the low intensity users. Additionally, this visitor is not expected to recreate in site surface waters. The exposure pathways identified for these high intensity users are discussed in more detail below.

Incidental Ingestion of Soil/Tailings

Few people intentionally ingest soil. However, it is believed that most people (especially children) do ingest small amounts of soil that adhere to the hands or other objects placed in the mouth. This exposure pathway is often one of the most important routes of human intake, so it was selected for quantitative evaluation.

Inhalation of Soil/Tailings in Air

Particles of contaminated soil/tailings may become resuspended in air, and visitors may breathe those particles while engages during recreational activities. Because high intensity activities may result in higher concentrations of contaminants being resuspended in air, this pathway was selected for further quantitative evaluation.

4.3 Summary of Pathways of Principal Concern

Based on the evaluations above, the following exposure scenarios are judged to be of sufficient potential concern to warrant quantitative exposure and risk analysis:

Population	Pathway
Low Intensity User	-Ingestion of Soil/Tailings -Ingestion of Surface Water -Dermal Exposure to Surface Water -Ingestion of Sediment -Inhalation of Particulates in Air
High Intensity User	-Ingestion of Soil/Tailings -Inhalation of Particulates in Air

5.0 QUANTIFICATION OF EXPOSURE AND RISK FROM NON-LEAD CONTAMINANTS

5.1 Quantification of Exposure

5.1.1 Basic Equation

The magnitude of human exposure to chemicals in an environmental medium is described in terms of the average daily intake (DI), which is the amount of chemical which comes into contact with the body by ingestion, inhalation, or dermal contact. The general equation for calculating the daily intake from contact with an environmental medium is (USEPA 1989a):

$$DI = C \times IR \times EF \times ED \times RBA / (BW \times AT)$$

where:

DI	=	daily intake of chemical (mg/kg-d)
C	=	concentration of chemical in an environmental medium (e.g., mg/kg)
IR	=	intake rate of the environmental medium (e.g., kg/day)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (years)
RBA	=	relative bioavailability of chemical in site medium
BW	=	body weight (kg)
AT	=	averaging time (days)

For mathematical and computational convenience, this equation is often written as:

$$DI = C \times HIF \times RBA$$

where:

HIF = "Human Intake Factor". For soil and dust ingestion, the units of HIF are kg/kg-day. The value of HIF is given by:

$$HIF = IR \times EF \times ED / (BW \times AT)$$

There is often wide variability in the amount of contact between different individuals within a population. Thus, human contact with an environmental media is best thought of as a distribution of possible values rather than a specific value. Usually, emphasis is placed on two different portions of this distribution:

- Average or Central Tendency Exposure (CTE) refers to individuals who have average or typical intake of environmental media.
- Upper Bound or Reasonable Maximum Exposure (RME) refers to people who are at the high end of the exposure distribution (approximately the 95th percentile). The RME scenario is intended to assess exposures that are higher than average, but are still within a realistic range of exposure.

The following sections list the exposure parameters used in the BHHRA for evaluation of low and high intensity recreational visitors by inhalation of particulates, incidental ingestion of soil/tailings, ingestion of and dermal contact with surface water (low intensity only), or incidental ingestion of sediment (low intensity only), along with the resulting HIF terms for CTE and RME exposure. Due to a lack of site specific data, recreational visitors, both low and high intensity, were assumed to visit the site either 50 (CTE) or 100 (RME) days per year based on a study conducted in Jefferson County, Colorado, which evaluated the frequency of open space visits over a 12-month period, as reported by 779 respondents (USEPA, 2001b).

5.1.2 Exposure Parameters

5.1.2.1 Recreational Visitor – Low Intensity Activities

Both Children (1-6 yrs) and adult recreational visitors have potential exposure pathways of soil/tailing ingestion and inhalation of particulates during low intensity activities and may be expected on a more infrequent basis to engage in recreational activities where exposure to sediments and surface water are plausible. The exposure frequency is estimated to be 50 days per year for CTE individuals and 100 days per year for RME individuals (USEPA, 2001b). Health endpoints include both cancer (via chronic exposure) and non-cancer health effects.

5.1.2.1.1 Soil/Tailings Ingestion

Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (USEPA 1989a, 1991b, 1993), as follows:

$$TWA - DI_S = \left(\frac{IR_c}{BW_c} \bullet \frac{EF_c \bullet ED_c}{(AT_c + AT_a)} + \frac{IR_a}{BW_a} \bullet \frac{EF_a \bullet ED_a}{(AT_c + AT_a)} \right)$$

where:

$TWA\text{-}DI_s$ = Time-weighted Daily Intake from ingestion of soil/tailings (mg/kg-d)
C_s = Concentration of chemical in soil/tailings (mg/kg)
IR = Intake rate (kg/day) when a child (IR_c) or an adult (IR_a)
BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)

Default values and assumptions recommended by USEPA (1989, 1991a, 1993a) for evaluation of exposure to soil/tailings are listed below. There are no data on ingestion rates of tailings by children or adults while engaged in recreational activities at this site. Therefore, based on professional judgment, ingestion rates of soil/tailings of 50 mg/event and 100 mg/event are assumed for adult and child RME low intensity visitors respectively. For CTE visitors, these values were assumed to be half of that attributable to the RME exposure (25 mg/day and 50 mg/day).

Exposure Parameters for Soil/Tailings Ingestion	CTE		RME	
	Child	Adult	Child	Adult
IR (kg/event)	5E-05	2.5E-05	1E-04	5E-05
BW (kg)	15	70	15	70
EF (events/year)	50	50	100	100
ED (years)	2	7	6	24
AT (non-cancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on the exposure parameters above, the HIFs for exposure of children and adults to soil/tailings are as follows:

Recreational Exposure to Soil/Tailings	HIF_{sd} (kg/kg-d)	
	CTE	RME
TWA-chronic (non-cancer)	1.4E-07	5.2E-07
TWA-lifetime (cancer)	1.8E-08	2.2E-07

Both children (1-6 yrs) and adult recreational visitors have potential exposure pathways of ingestion of sediments, dermal contact with surface water, and ingestion of surface water. The exposure frequency is estimated to be 5 days per year for CTE individuals and 10 days per year for RME individuals, based on the assumption that the low intensity visitor is exposed to these media during 1 out of every 10 standard visits. Health endpoints include both cancer (via chronic exposure) and non-cancer health effects.

5.1.2.1.2 Inhalation of Particulates

The basic equation recommended by EPA (1989) for evaluation of risks due to inhalation exposure to a chemical in air is:

$$TWA - DI_p = C_p\left(\frac{IR_c}{BW_c} \bullet \frac{ET_c \bullet EF_c \bullet ED_c}{(AT_c + AT_a)} + \frac{IR_a}{BW_a} \bullet \frac{ET_a \bullet EF_a \bullet ED_a}{(AT_c + AT_a)}\right)$$

where:

TWA-DIp = Time-weighted Daily Intake from inhalation of particulates
Cp = Concentration of chemical in air (mg/m3)
IR = Breathing rate of air (m3/hour) when a child (IRc) or an adult (IRa)
ET = Exposure time (hours/day) when a child (ETc) or an adult (ETa)

EF = Exposure frequency (days/yr) when a child (EFc) or an adult (EFa)
ED = Exposure duration (years) when a child (EDc) or an adult (EDa)
AT = Averaging time (days) while a child (ATc) or an adult (ATa)
BW = Body weight (kg) when a child (BWc) or an adult (BWa)
AT = Averaging time (days)

Default values and assumptions recommended by EPA (1989, 1991, 1993) for evaluation of exposure to particulates in air are listed below. Inhalation rates of 1.6 m3/hr for children and 2.4 m3/hr for adults are based on the average of medium and heavy activity inhalation rates for these age groups. This information is from the 1997 Exposure Factors Handbook and was used as inputs in the Rocky Flats Task 3 Report (EPA, 2001). The Exposure Time was based on the 1995 Boulder County open space survey (EPA, 2001) of time spent on site (19% < 1 hour, 71% 1-3 hours, 9% 4-6 hours, and 1% >7 hours). Values of 1.5 and 2.5 hours/day were selected for the CTE and RME exposures, respectively. Although this information pertains to a different site, the values are judged to be applicable at Richardson Flats. The Particulate Emissions Factor (PEF) is the default value established by EPA.

Exposure Parameters for Inhalation of Particulates	CTE		RME	
	Child	Adult	Child	Adult
IR (m^3/hr)	1.6	2.4	1.6	2.4
BW (kg)	15	70	15	70
PEF (kg/m^3)	7.6E-10	7.6E-10	7.6E-10	7.6E-10
ET (hr/day)	1.5	1.5	2.5	2.5
EF (days/yr)	50	50	100	100
ED (years)	2	7	6	24
AT (non-cancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on the exposure parameters above, the HIFs for exposure of children and adults to particulates are as follows:

Recreational Exposure to Particulates	HIF_{sd} (kg/kg-d)	
	CTE	RME
TWA-chronic (non-cancer)	1.0E-02	3.3E-02
TWA-lifetime (cancer)	1.8E-03	1.4E-02

5.1.2.1.3 Ingestion of Sediments

The basic equation used to assess risks from incidental ingestion of sediments by recreational visitors while visiting water areas is as follows. Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (USEPA 1989a, 1991b, 1993a):

$$TWA - DI_s = C_s\left(\frac{IR_c}{BW_c} \bullet \frac{EF_c \bullet ED_c}{(AT_c + AT_a)} + \frac{IR_a}{BW_a} \bullet \frac{EF_a \bullet ED_a}{(AT_c + AT_a)}\right)$$

where:

TWA-DI_s = Time-weighted Daily Intake from ingestion of sediment (mg/kg-d)
C_s = Concentration of chemical in sediment (mg/kg)
IR = Intake rate (kg/day) when a child (IR_c) or an adult (IR_a)
BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)

There are no data on ingestion rates of sediments by visitors while engaged in recreational activities along the river or in ponded water areas at the site. Therefore, in the absence of data, ingestion rates of soil/tailings of 25 mg/day and 50 mg/day are assumed for adult and child RME visitors respectively. For CTE visitors, these values were assumed to be half of that attributable to the RME exposure (12.5 mg/day and 25 mg/day). This is equivalent to ½ of the quantity consumed by the low intensity recreational visitor from soil/tailings ingestion.

The exposure parameters are summarized below:

Exposure Parameters for Ingestion of Sediments	CTE		RME	
	Child	Adult	Child	Adult
IR (kg/day)	2.5E-05	1.3E-05	5E-05	2.5E-05
BW (kg)	15	70	15	70
EF (days/year)	5	5	10	10
ED (years)	2	7	6	24
AT (non-cancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on these exposure parameters, the HIF values for exposure of visitors to sediments are as follows:

Recreational Exposure to Sediments	HIF (kg/kg-d)	
	Average	RME
Chronic (non-cancer)	7.0E-09	2.6E-08
Lifetime (cancer)	9.0E-10	1.1E-08

5.1.2.1.4 Dermal Contact with Surface Water

The basic equation recommended by EPA (1989) for evaluation of dermal exposure to a chemical dissolved in water is as follows. Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (EPA 1989, 1991, 1993a):

$$AD_{sw} = C_{sw}\left(\frac{SA_c \bullet PC \bullet ET_c \bullet 1E-03}{BW_c} \bullet \frac{EF_c \bullet ED_c}{(AT_c + AT_a)} + \frac{SA_a \bullet PC \bullet ET_a \bullet 1E-03}{BW_a} \bullet \frac{EF_a \bullet ED_a}{(AT_c + AT_a)}\right)$$

where:

Adsw = Absorbed dose from dermal contact with surface water (mg/kg-d)
Csw = Concentration of chemical in surface water (mg/L)
SA = Surface area exposed (cm2) for child (SAc) or adult (SAa)
PC = Chemical-specific permeability constant (cm/hr)
ET = Exposure time (hr/day) for child (ETc) or adult (ETa)
1E-03 = Conversion factor (L/cm3)
EF = Exposure frequency (days/yr) child (EFc) or adult (EFa)
ED = Exposure duration (yrs) for child (EDc) or adult (EDa)
BW = Body weight (kg) child (BWc) or adult (BWa)
AT = Averaging time (days) for child (ATc) or adult (ATa)

It is assumed that dermal exposure of a recreation visitor to water occurs mainly while wading near the river edge or ponded areas, and that dermal contact is mainly restricted to the lower extremities (upper and lower legs and feet) as well as the hands. The surface area for these body parts in children and adults is the 50th percentile for hands, arms, and lower legs (EPA, 1997) (SAF, 2000). No site-specific data on recreation frequency or duration of wading activities per trip are available, so values of 5 (CTE) to 10 (RME) days/year, and 0.5 (CTE) to 1.5 (RME) hours/day are assumed. The exposure time is based on the FE Warren site (SAF, 2000), where estimated time spent in surface waters were evaluated. The value of PC is chemical specific, and few measured values are available for metals. Therefore, the EPA (1992b) suggests using a PC value of 1E-03 cm/hr as a conservative estimate. Other exposure parameters are the same as described above. These exposure parameters are summarized below.

Exposure Parameters for Dermal Contact with Surface Water	CTE		RME	
	Child	Adult	Child	Adult
SA (cm^2)	3,800	5,000	3,800	5,000
PC (cm/hr)	1E-03	1E-03	1E-03	1E-03
BW (kg)	15	70	15	70
ET (hours/day)	0.5	0.5	1.5	1.5
EF (days/year)	5	5	10	10
ED (years)	2	7	6	24
AT (non-cancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on these exposure parameters, the HIF values for dermal exposure of low intensity recreational visitors to surface water are as follows:

Recreational Exposure to Surface Water	HIF (kg/kg-d)	
	Average	RME
Chronic (non-cancer)	7.7E-07	4.4E-06
Lifetime (cancer)	9.8E-08	1.9E-06

5.1.2.1.5 Ingestion of Surface Water

The basic equation for evaluation of exposure from ingestion of surface water while participating in water-based recreational activities is as follows. Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (USEPA 1989a, 1991b, 1993a):

$$TWA - DI_w = C_w\left(\frac{IR_c}{BW_c} \bullet \frac{ET_c \bullet EF_c \bullet ED_c}{(AT_c + AT_a)} + \frac{IR_a}{BW_a} \bullet \frac{ET_a \bullet EF_a \bullet ED_a}{(AT_c + AT_a)}\right)$$

where:

$TWA\text{-}DI_s$ = Time-weighted Daily Intake from ingestion of water (mg/kg-d)
C_s = Concentration of chemical in surface water (mg/L)
IR = Intake rate (L/day) when a child (IR_c) or an adult (IR_a)

BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
ET = Exposure time (hours/day) when a child (ET_c) or an adult (ET_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)

The rate of water ingestion by recreational visitors was based on values applied in the FE Warren Site Risk Assessment (SAF, 2000). An incidental water ingestion rate of 30 mL/hour is the basis for the 10 mL/day value proposed in the Draft Water Quality Criteria Methodology Revisions (SAF, 2000) and will be used as the RME at this site. The USEPA (1989a) recommends a default surface water ingestion rate of 50 mL/hr while swimming. However, recognizing that splashing or hand-to face contact while wading might result in only a very small amount of water in or near the mouth, it is thought that this value is too high under this scenario. Based on this reasoning, a CTE value of 5 mL/hour was assumed. Exposure times are the same as those presented for dermal exposure. These exposure parameters are summarized below:

Exposure Parameters for Ingestion of Surface Water	CTE		RME	
	Child	Adult	Child	Adult
IR (mL/hour)	5	5	30	30
BW (kg)	15	70	15	70
ET (hours/day)	0.5	0.5	1.5	1.5
EF (days/year)	5	5	10	10
ED (years)	2	7	6	24
AT (non-cancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on these exposure parameters, the HIF values for ingestion of surface water by recreational visitors are as follows:

Recreational Exposure to Surface Water	HIF_{sw} (L/kg-d)	
	CTE	RME
Chronic (non-cancer)	8.9E-07	3.1E-05
Lifetime (cancer)	1.1E-07	1.3E-05

5.1.2.2 Recreational Visitor – High Intensity Activities

Adult recreational visitors have potential exposure pathways of soil/tailing ingestion and inhalation of particulates during high intensity activities (e.g. horseback riding, ATV use, dirt-biking, soccer and baseball). The exposure frequency is estimated to be 50 days per year for CTE individuals and 100 days per year for RME individuals (USEPA, 2001b). Health endpoints include both cancer (via chronic exposure) and non-cancer health effects.

5.1.2.2.1 Soil/Tailings Ingestion

The basic equation used to assess risks from incidental ingestion of tailings or contaminated soil by recreational visitors is as follows:

$$DI_t = C_t\left(\frac{IR_t}{BW}\right)\left(\frac{EF_t \bullet ED}{AT}\right)$$

where:

DI_t = Daily intake of chemical from ingestion of soil/tailings (mg/kg-d)
C_t = Concentration of chemical in soil tailings (mg/kg)
IR_t = Intake rate of tailings (kg/event)
BW = Body weight of the exposed person (kg)
EF_t = Exposure frequency to soil tailings (days/year)
ED = Exposure duration (years)
AT = Averaging time (days)

There are no data on ingestion rates of tailings by adults while engaged in high intensity recreational activities at this site. Therefore, based on professional judgment, ingestion rates of soil/tailings of 50 mg/day and 100 mg/day are assumed for CTE and RME exposure, respectively.

The exposure parameters are summarized below:

Exposure Parameter for Soil/Tailings Ingestion	CTE	RME
IR (kg/event)	5E-05	1E-04
BW (kg)	70	70
EF (events/year)	50	100
ED (years)	7	24
AT (non-cancer effects) (days)	6·365	24·365
AT (cancer effects) (days)	70·365	70·365

Based on these exposure parameters, the HIF values for exposure of high intensity recreational visitors to tailings and contaminated soil are as follows:

Recreational Exposure to Soil/Tailings	HIF (kg/kg-d)	
	CTE	RME
Chronic (non-cancer)	9.8E-08	3.9E-07
Lifetime (cancer)	9.8E-09	1.3E-07

5.1.2.2.2 Inhalation of Particulates

The basic equation recommended by EPA (1989) for evaluation of risks due to inhalation exposure to a chemical in air is:

$$DI_{air} = C_a \bullet \left(\frac{BR}{BW}\right) \bullet \left(\frac{ET \bullet EF \bullet ED}{AT}\right)$$

where:

DI_{air} = Risk from inhalation exposure to a chemical in air
C_{air} = Concentration of chemical in air (mg/m^3)
BR = Breathing rate of air (m^3/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/yr)
ED = Exposure duration (yrs)
BW = Body weight (kg)
AT = Averaging time (days)
TF_{inhal} = Toxicity factor for the inhalation pathway

Default values and assumptions recommended by EPA (1989, 1991, 1993a) for evaluation of exposure to particulates in air are listed below. An inhalation rate of 2.4 m3/hr for adults was based on the average of medium and heavy activity inhalation rates for this age group. This information is from the 1997 Exposure Factors Handbook and was used as inputs in the Rocky Flats Task 3 Report (EPA, 2001). The Exposure Time was based on the 1995 Boulder County open space survey (EPA, 2001) of time spent on site (19% < 1 hour, 71% 1-3 hours, 9% 4-6 hours, and 1% >7 hours). Values of 1.5 and 2.5 hours/day were selected for the CTE and RME exposures, respectively. Although this information pertains to a different site, the values are judged to be applicable at Richardson Flats. The PEF value is based on a value established for all-terrain vehicle (ATV) usage at an old mine tailings site (Arizona Department of Health Services) and is thought to be appropriate for use at this site.

Exposure Parameters for Inhalation of Particulates	CTE	RME
BR (m^3/hr)	2.4	2.4
BW (kg)	70	70
PEF (kg/m^3)	4.6E-09	4.6E-09
ET (hr/day)	1.5	2.5
EF (days/yr)	50	100
ED (years)	7	24
AT (non-cancer effects) (days)	6·365	24·365
AT (cancer effects) (days)	70·365	70·365

Based on the exposure parameters above, the HIFs for exposure to particulates are as follows:

Recreational Exposure to Particulates	HIF (kg/kg-d)	
	CTE	RME
Chronic (non-cancer)	7.0E-03	2.3E-02
Lifetime (cancer)	7.0E-04	8.1E-03

5.1.3 Concentration of Non-Lead COPCs (C)

Arsenic concentrations in site media are summarized below.

Media	Avg (ppm)	Min (ppm)	Max (ppm)	95th UCL (ppm)
Sediment	162	101	310	194
Surface Water	0.009	0.003	0.75	0.014
Soil/Tailings	41	2.5	243	54

Estimated arsenic concentrations in air for low intensity and high intensity users are summarized below.

User	Concentration (mg/m^3)
Low Intensity User	4.2E-08
High Intensity User	2.5E-07

Note: The PEF for low intensity users is 7.6E-10 kg/m^3 and the PEF for high intensity users is 4.6E-09 kg/m^3 .

5.1.4 Relative Bioavailability (RBA)

Accurate assessment of the human health risks resulting from oral exposure to metals requires knowledge of the amount of metal absorbed from the gastrointestinal tract into the body. This information is especially important for environmental media such as soil or mine wastes, because metals in these media may exist, at least in part, in a variety of poorly water soluble minerals, and may also exist inside particles of inert matrix such as rock or slag. These chemical and physical properties may tend to influence (usually decrease) the absorption (bioavailability) of the metals when ingested.

At this site, no site-specific data are available for the bioavailability of arsenic in soils/tailings, therefore the Region 8 USEPA default value of 0.80 was utilized (USEPA, 1993b). For water, and RBA of 1.0 was assumed.

5.2 Toxicity Assessment

The toxic effects of a chemical generally depend not only upon the inherent toxicity of the compounds and the level of exposure (dose), but also on the route of exposure (oral, inhalation, dermal) and the duration of exposure (subchronic, chronic or lifetime). Thus, a full description of the toxic effects of a chemical includes a listing of what adverse health effects the chemical may cause, and how the occurrence of these effects depend upon dose, route, and duration of exposure.

The toxicity assessment process is usually divided into two parts: the first characterizes and quantifies the non-cancer effects of the chemical, while the second addresses the cancer effects of the chemical. This two-part approach is employed because there are typically major differences in the time-course of action and the shape of the dose-response curve for cancer and non-cancer effects.

Non-Cancer Effects

Essentially all chemicals can cause adverse health effects if given at a high enough dose. However, when the dose is sufficiently low, typically no adverse effect is observed. Thus, in characterizing the non-cancer effects of a chemical, the key parameter is the threshold dose at which an adverse effect first becomes evident. Doses below the threshold are considered to be safe, while doses above the threshold are likely to cause an effect.

The threshold dose is typically estimated from toxicological data (derived from studies of humans and/or animals) by finding the highest dose that does not produce an observable adverse effect, and the lowest dose which does produce an effect. These are referred to as the "No-observed-adverse-effect-level" (NOAEL) and the "Lowest-observed-adverse-effect-level" (LOAEL), respectively. The threshold is presumed to lie in the interval between the NOAEL and the LOAEL. However, in order to be conservative (protective), non-cancer risk evaluations are not based directly on the threshold exposure level, but on a value referred to as the Reference Dose (RfD). The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

The RfD is derived from the NOAEL (or the LOAEL if a reliable NOAEL is not available) by dividing by an "uncertainty factor". If the data are from studies in humans, and if the observations are considered to be very reliable, the uncertainty factor may be as small as 1.0. However, the uncertainty factor is

normally at least 10, and can be much higher if the data are limited. The effect of dividing the NOAEL or the LOAEL by an uncertainty factor is to ensure that the RfD is not higher than the threshold level for adverse effects. Thus, there is always a "margin of safety" built into an RfD, and doses equal to or less than the RfD are nearly certain to be without any risk of adverse effect. Doses higher than the RfD may carry some risk, but because of the margin of safety, a dose above the RfD does not mean that an effect will necessarily occur.

Cancer Effects

For cancer effects, the toxicity assessment process has two components. The first is a qualitative evaluation of the weight of evidence that the chemical does or does not cause cancer in humans. Typically, this evaluation is performed by the USEPA, using the system summarized in the table below:

Category	Meaning	Description
A	Known human carcinogen	Sufficient evidence of cancer in humans.
B1	Probable human carcinogen	Suggestive evidence of cancer incidence in humans.
B2	Probable human carcinogen	Sufficient evidence of cancer in animals, but lack of data or insufficient data from humans.
C	Possible human carcinogen	Suggestive evidence of carcinogenicity in animals.
D	Cannot be evaluated	No evidence or inadequate evidence of cancer in animals or humans.

For chemicals which are classified in Group A, B1, B2, or C, the second part of the toxicity assessment is to describe the carcinogenic potency of the chemical. This is done by quantifying how the number of cancers observed in exposed animals or humans increases as the dose increases. Typically, it is assumed that the dose response curve for cancer has no threshold, arising from the origin and increasing linearly until high doses are reached. Thus, the most convenient descriptor of cancer potency is the slope of the dose-response curve at low dose (where the slope is still linear). This is referred to as the Slope Factor (SF), which has dimensions of risk of cancer per unit dose.

Estimating the cancer Slope Factor is often complicated by the fact that observable increases in cancer incidence usually occur only at relatively high doses, frequently in the part of the dose-response curve that is no longer linear. Thus, it is necessary to use mathematical models to extrapolate from the observed high dose data to the desired (but unmeasurable) slope at low dose. In order to account for the uncertainty in this extrapolation process, USEPA typically chooses to employ the upper 95th confidence limit of the slope as the Slope Factor. That is, there is a 95% probability that the true cancer potency is lower than the value chosen for the Slope Factor. This approach ensures that there is a margin of safety in cancer risk estimates.

5.2.1 Adverse Effects of Arsenic

Excess exposure to arsenic is known to cause a variety of adverse health effects in humans. These effects depend on exposure level (dose) and also on exposure duration. The following sections discuss the most characteristic of these effects.

Noncancer Effects

Oral exposure to high doses of arsenic produces marked acute irritation of the gastrointestinal tract, leading to nausea and vomiting. Symptoms of chronic ingestion of lower levels of arsenic often begin with a vague weakness and nausea. As exposure continues, symptoms become more characteristic and include diarrhea, vomiting, decreased blood cell formation, injury to blood vessels, damage to kidney and liver, and impaired nerve function that leads to "pins and needles" sensations in the hands and feet. The most diagnostic sign of chronic arsenic exposure is an unusual pattern of skin abnormalities, including dark and white spots and a pattern of small "corns," especially on the palms and soles (ATSDR 1991).

The long-term (chronic) average daily intake of arsenic that produces these effects varies from person to person. In a large epidemiological study, Tseng et al. (1968) reported skin and vascular lesions in humans exposed to 1.4E-02 mg/kg/day or more arsenic through drinking water in Taiwan. These effects were not observed in a control population ingesting 8.0E-04 mg/kg/day. Based on this, the USEPA calculated a chronic oral reference dose (RfD) of 3.0E-04 mg/kg/day (USEPA 1996). This is a dose which is believed to be without significant risk of causing adverse noncancer effects in even the most susceptible humans following chronic exposure.

Carcinogenic Effects

There have been a number of epidemiological studies in humans which indicate that chronic inhalation exposure to arsenic is associated with increased risk of lung cancer (USEPA 1984, ATSDR 1991). In addition, there is strong evidence from a number of human studies that oral exposure to arsenic increases the risk of skin cancer (USEPA 1984, ATSDR 1991). The most common type of cancer is squamous cell carcinoma, which appears to develop from some skin corns. In addition, basal cell carcinoma may also occur, typically arising from cells not associated with the corns. Although these cancers may be easily removed, they can be painful and disfiguring and can be fatal if left untreated. Although the evidence is limited, there are some reports which indicate that chronic oral arsenic exposure may also increase risk of internal cancers, including cancer of the liver, bladder and lung, and that inhalation exposure may also increase risk of gastrointestinal, renal or bladder cancers (ATSDR 1991). Based on these data, USEPA has assigned arsenic to cancer weight of evidence Category A.

The amount of arsenic ingestion that leads to skin cancer is controversial. Based on a study of skin cancer incidence in Taiwanese residents exposed mostly to As(+3) in drinking water (Tseng et al. 1968, USEPA 1984), the USEPA has calculated a unit risk of 5E-05 (ug/L)-1 corresponding to an oral slope factor of 1.5E+00 (mg/kg/day)-1 (IRIS 1998). This study has been criticized on several grounds, including uncertainty about exposure levels, possible effects of poor nutrition in the exposed population, potential exposure to other substances besides arsenic, and lack of blinding in the examiners. Consequently, some quantitative uncertainty exists in the cancer potency factor derived from the Tseng data. Nevertheless, these criticisms do not challenge the fundamental conclusion that arsenic ingestion is associated with increased risk of skin cancer, and the Tseng study is considered to be the best study currently available for quantitative estimation of skin cancer risk.

There are good data to show that arsenic is metabolized by methylation in the body, and some researchers have suggested that this could lead to a threshold dose below which cancer will not occur. Although there are data which are consistent with this view, the USEPA has reviewed the available information (USEPA 1988) and has concluded that the data are insufficient at present to establish that there is a threshold for arsenic-induced cancer.

5.2.2 Summary of Oral Toxicity Values

The toxicity factors derived by the USEPA for oral exposure to the site COPCs are summarized below:

Chemical	Non-Cancer RfD (mg/kg-day)	Cancer	
		Weight-of-Evidence	oral SF $(mg/kg\text{-}day)^{-1}$
Arsenic	3E-04	A	1.5

5.3 Risk Characterization

5.3.1 Overview

Risk characterization is the process of combining information on doses (Section 5.1) with toxicity information (Section 5.2) in order to estimate the nature and likelihood of adverse effects occurring in members of the exposed population. As explained earlier, this process is usually performed in two steps, the first addressing noncancer risks from chemicals of concern, and the second addressing cancer risks. The basic methods used to quantify noncancer and cancer risks are summarized below.

5.3.2 Noncancer Risk

Basic Equations

The potential for noncancer effects from exposure to a chemical is evaluated by comparing the estimated daily intake of the chemical over a specific time period with the RfD for that chemical derived for a similar exposed period. This comparison results in a noncancer Hazard Quotient, as follows (USEPA 1989a):

$$HQ = DI/RfD$$

where:

HQ = Hazard Quotient
DI = Daily Intake (mg/kg-day)
RfD = Reference Dose (mg/kg-day)

If the HQ for a chemical is equal to or less than one (1E+00), it is believed that there is no appreciable risk that noncancer health effects will occur. If an HQ exceeds 1E+00, there is some possibility that noncancer effects may occur, although an HQ above 1E+00 does not indicate an effect will definitely occur. This is because of the margin of safety inherent in the derivation of all RfD values. However, the larger the HQ value, the more likely it is that an adverse effect may occur. If more than one chemical affects the same target tissue or organ system (e.g., the liver), then the total risk of adverse effects in that tissue is referred to as the Hazard Index (HI), and is estimated by summing the HQ values for all chemicals that act on that tissue.

5.3.3 Cancer Risk

Basic Equations

The risk of cancer from exposure to a chemical is described in terms of the probability that an exposed individual will develop cancer because of that exposure by age 70. For each chemical of concern, this value is calculated from the daily intake of the chemical from the site, averaged over a lifetime (DI_L), and the SF for the chemical, as follows (USEPA 1989a):

$$\text{Cancer Risk} = 1 - \exp(-DI_L \times SF)$$

In most cases (except when the product of DI_L*SF is larger than about 0.01), this equation may be accurately approximated by the following:

$$\text{Cancer Risk} = DI_L \times SF$$

The level of cancer risk that is of concern is a matter of individual, community and regulatory judgement. However, the USEPA typically considers risks below 1E-06 to be so small as to be negligible, and risks above 1E-04 to be sufficiently large that some sort of action or intervention is usually needed (USEPA, 1991b). Risks between 1E-04 and 1E-06 usually do not require action (USEPA, 1991b), but this is evaluated on a case by case basis.

5.3.4 Results

Non-Cancer Risks

The following table summarize the estimated HQ values for both low and high intensity recreational visitors exposed to arsenic in site media. As shown, none of the media exceeds an HQ of 1E+00 for either low or high intensity use scenarios for either average or RME exposure conditions. The majority of observed risk is attributable to soil/tailings ingestion.

Population	Exposure Pathway	Average	RME
Low Intensity	Sediment Ingestion	3.7E-03	1.4E-02
	Surface Water Ingestion	4.1E-05	1.4E-03
	Dermal Contact with Surface Water	3.5E-05	2.0E-04
	Soil/Tailings Ingestion	2.1E-02	7.7E-02
	Inhalation of Particulates in Air	1.2E-06	3.8E-06
High Intensity	Soil/Tailings Ingestion	1.4E-02	5.8E-02
	Inhalation of Particulates in Air	4.8E-06	9.0E-09
Total Risk Low Intensity User		*2.4E-02*	*9.3E-02*
Total Risk High Intensity User		*1.4E-02*	*5.8E-02*

Cancer Risks

Using these equations, the estimated lifetime average and RME daily intake values (calculated as described in Section 5.1) for both low and high intensity users were combined with the oral slope factor for arsenic discussed in Section 5.2. The detailed calculations are presented in Appendix D, and the results are summarized in the following table. As seen, the majority of observed risk is attributable to soil/tailing ingestion. However, total cancer risks do not exceed a level of 1E-04 for low intensity and high intensity users using either average or RME exposure assumptions.

Population	Exposure Pathway	Average	RME
Low Intensity	Sediment Ingestion	2.7E-07	3.3E-06
	Surface Water Ingestion	2.4E-09	2.7E-07
	Dermal Contact with Surface Water	2.0E-09	3.9E-08
	Soil/Tailings Ingestion	1.5E-06	1.9E-05
	Inhalation of Particulates in Air	8.4E-10	9.0E-09
High Intensity	Soil/Tailings Ingestion	8.1E-07	1.1E-05
	Inhalation of Particulates in Air	2.7E-09	3.1E-08
Total Risk Low Intensity User		*1.8E-06*	*2.2E-05*
Total Risk High Intensity User		*8.1E-07*	*1.1E-05*

5.4 Uncertainties

It is important to recognize that the exposure and risk calculations for the COPCs presented in this section are based on a number of assumptions, and that these assumptions introduce uncertainty into the dose and risk estimates. Assumptions are required because of data gaps in our understanding of the toxicity of chemicals, and in our ability to estimate the true level of human exposure to chemicals. In most cases, assumptions employed in the risk assessment process to deal with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate than an underestimate of risk. It is important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site.

5.4.1 Uncertainties in Concentration Estimates

Evaluation of human health risk at any particular location requires accurate information on the average concentration level of a COPC at that location. However, concentration values may vary from sample to sample, so the USEPA recommends that the 95% upper confidence limit of the mean be used in evaluation of both average and RME exposure and risk. This approach typically ensures that all of the risk estimates are more likely to be high than low.

Risks from exposure to non-lead COPCs were evaluated based on surficial soil data. This decision was based on the assumptions that recreational users be most likely to be exposed to surficial soils based on their activities. If the depth distribution for arsenic mimics that observed for lead, risks from exposure to subsurface soils will be similar or less than those observed for surface soils. However, if concentrations for these analytes are found to increase as a function of depth, the risks based on surface soil exposure will underestimate risks for those individuals exposed to buried materials. A quick review of the data show that the maximum arsenic concentration in soil/tailings observed at the site at any depth is 637

mg/kg. Using this value in the risk calculations, total non-cancer risks to the low and high intensity recreational user are 9.0E-01and 6.6E-01, respectively. Cancer risks 2.1E-04 and 1.3E-04, respectively.

5.4.2 Uncertainties in Human Intake

As discussed in Section 5.1, there is usually wide variation between different individuals with respect to the level of contact they may have to chemicals in the environment. This introduces uncertainty into the most appropriate values to use for exposure parameters such as soil and dust intake rates, number of years at the residence, etc. Because of the uncertainty in the most appropriate values for these parameters, the USEPA generally recommends default values that are more likely to overestimate than underestimate exposure and risk.

5.4.3 Uncertainties in Toxicity Values

One of the most important sources of uncertainty in a risk assessment is in the RfD values used to evaluate noncancer risk and in the slope factors used to quantify cancer risk. In many cases, these values are derived from a limited toxicity database, and this can result in substantial uncertainty, both quantitatively and qualitatively. For example, there is continuing scientific debate on the accuracy of the oral slope factor and the oral Reference Dose for arsenic and whether or not they are accurate and appropriate for predicting hazards from relatively low dose exposures. In order to account for these and other uncertainties associated with the evaluation of toxicity data, both RfDs and SFs are derived by the USEPA in a way that is intentionally conservative; that is, risk estimates based on these RfDs and SFs are more likely to be high than low.

5.4.4 Uncertainties in Absorption from Soil

Another important source of uncertainty regarding the toxicity of arsenic is the degree to which it is absorbed into the body after ingestion of soil. Toxicity factors (RfD, oSF) for arsenic are based on observed dose response relationships when exposure occurs by ingestion of arsenic dissolved in water. If arsenic in soil is not absorbed as well as arsenic in water, use of unadjusted toxicity factors will tend to overestimate risk. At this site, the USEPA default relative bioavailability factor for arsenic of 0.8 was used for soil/tailings and sediment. However, use of this factor may or may not be reflective of the actual site RBA. Tests in juvenile swine have shown that RBA values in site soils may be higher or lower than the default value based on soil characteristics such as mineral phase, particle size distribution, etc.

5.4.5 Uncertainties from Pathways Not Evaluated

As discussed in Section 4, not all possible pathways of human exposure to site COPCs were evaluated quantitatively in this risk assessment, and omission of these pathways presumably leads to some degree of underestimation of total risk. For some of these pathways (dermal absorption from soil on the skin), the underestimation of risk is believed to be minimal (see Appendix C). In the case of ingestion of site biota, the magnitude of the underestimation is less certain. Studies at other sites (Sverdrup, 1995) suggest that exposure by this pathways is probably not as large as by oral exposure, but that the contribution is not completely negligible. However, the magnitude of this risk contributed by pathway is expected to vary widely from site to site, depending on the amount of uptake from soil into the biota and the amount and type of biota actually consumed by site visitors. At this time, it is not thought that this pathway is a prevalent pathway of exposure to area visitors.

6.0 RISKS FROM LEAD

As noted earlier, risks from lead are evaluated using a somewhat different approach than for most other metals. First, because lead is widespread in the environment, exposure can occur by many different pathways. Thus, lead risks are usually based on consideration of total exposure (all pathways) rather than just to site-related exposures. Second, because studies of lead exposures and resultant health effects in humans have traditionally been described in terms of blood lead level (PbB, expressed in units of ug/dL), lead exposures and risks are typically assessed using an uptake-biokinetic model rather than an RfD approach. Therefore, calculating the level of exposure and risk from lead in soil also requires assumptions about the level of lead in other media, and also requires use of pharmacokinetic parameters and assumptions that are not needed in traditional methods.

For residential land use, the sub-population of chief concern is young children. This is because young children 1) tend to have higher exposures to lead in soil, dust and paint, 2) tend to have a higher absorption fraction for ingested lead, and 3) are more sensitive to the toxic effects of lead than are older children or adults. For non-residential exposures (e.g., recreation, occupational) the population of chief concern are older children and young adults. When adults are exposed, the sub-population of chief concern is pregnant women and women of child-bearing age, since the blood lead level of a fetus is nearly equal to the blood lead level of the mother (Goyer 1990).

At this site, the BHHRA focuses on risks to recreational visitors. For low-intensity users, the visitors were assumed to range from young children to adults, whereas high-intensity visitors were assumed to be teenagers and adults. Because the effects of lead exposure are evaluated differently for young children than they are for adults, two separate modeling approaches were used to evaluate risks to the recreational visitors: one specific to children (low-intensity only) and one appropriate for older individuals (low- and high-intensity). These approaches are described in further detail below (Section 6.2).

6.1 Adverse Effects of Lead Exposure

Excess exposure to lead can result in a wide variety of adverse effects in humans. Chronic low-level exposure is usually of greater concern for young children than older children or adults. There are several reasons for this focus on young children, including the following: 1) young children typically have higher exposures to lead-contaminated media per unit body weight than adults, 2) young children typically have higher lead absorption rates than adults, and 3) young children are more susceptible to effects of lead than are adults. The following sections summarize the most characteristic and significant of the adverse effects of lead on children, and current guidelines for classifying exposures as acceptable or unacceptable.

6.1.1 Neurological Effects

The effect of lead that is usually considered to be of greatest concern in children is impairment of the nervous system. Many studies have shown that animals and humans are most sensitive to the effects of lead during the time of nervous system development, and because of this, the fetus, infants and young children (0-6 years of age) are particularly vulnerable. The effects of chronic low-level exposure on the nervous system are subtle, and normally cannot be detected in individuals, but only in studies of groups of children. Common measurement endpoints include various types of tests of intelligence, attention span, hand-eye coordination, etc. Most studies observe effects in such tests at blood lead levels of 20-30 ug/dL, and some report effects at levels as low as 10 ug/dL and even lower. Such effects on the nervous system are long-lasting and may be permanent.

6.1.2 *Effects on Pregnancy and Fetal Development*

Studies in animals reveal that high blood lead levels during pregnancy can cause fetotoxic and teratogenic effects. Some epidemiologic studies in humans have detected an association between elevated blood lead levels and endpoints such as decreased fetal size or weight, shortened gestation period, decreased birth weight, congenital abnormalities, spontaneous abortion and stillbirth (USEPA 1986). However, these effects are not detected consistently in different studies, and some researchers have detected no significant association between blood lead levels and signs of fetotoxicity. On balance, these data provide suggestive evidence that blood lead levels in the range of 10-15 ug/dL may cause small increases in the risk of undesirable prenatal as well as postnatal effects, but the evidence is not definitive.

6.1.3 *Effects on Heme Synthesis*

A characteristic effect of chronic high lead exposure is anemia stemming from lead-induced inhibition of heme synthesis and a decrease in red blood cell life span. ACGIH (1995) concluded that decreases in ALA-D activity (a key early enzyme involved in heme synthesis) can be detected at blood lead levels below 10 ug/dL. Heme synthesis is inhibited not only in red blood cells but in other tissues. Several key enzymes that contain heme, including those needed to form vitamin D, also show decreased activity following lead exposure (USEPA 1986). The Centers for Disease Control (CDC 1991) reviewed studies on the synthesis of an active metabolite of vitamin D and found that impairment was detectable at blood lead levels of 10 - 15 ug/dL.

6.1.4 *Cancer Effects*

Studies in animals indicate that chronic oral exposure to very high doses of lead salts may cause an increased frequency of tumors of the kidney (USEPA 1989b, ACGIH 1995). However, there is only limited evidence suggesting that lead may be carcinogenic in humans, and the noncarcinogenic effects on the nervous system are usually considered to be the most important and sensitive endpoints of lead toxicity (USEPA 1988). ACGIH (1995) states that there is insufficient evidence to classify lead as a human carcinogen.

6.1.5 *Current Guidelines for Protecting Children from Lead*

It is currently difficult to identify what degree of lead exposure, if any, can be considered safe for infants and children. As discussed above, some studies report subtle signs of lead-induced effects in children and perhaps adults beginning at around 10 ug/dL or even lower, with population effects becoming clearer and more definite in the range of 30-40 ug/dL. Of special concern are the claims by some researchers that effects of lead on neurobehavioral performance, heme synthesis, and fetal development may not have a threshold value, and that the effects are long-lasting (USEPA 1986). On the other hand, some researchers and clinicians believe the effects that occur in children at low blood lead levels are so minor that they need not be cause for concern.

After a thorough review of all the data, the USEPA identified 10 ug/dL as the concentration level at which effects begin to occur that warrant avoidance, and has set as a goal that there should be no more than a 5% chance that a child will have a blood lead value above 10 ug/dL (USEPA, 1991b). Likewise, the Centers for Disease Control (CDC) has established a guideline of 10 ug/dL in preschool children which is believed to prevent or minimize lead-associated cognitive deficits (CDC 1991).

6.2 Evaluation of Lead Risks to Recreational Visitors

6.2.1 Evaluation of Lead Risks to Recreational Children

The standard model developed by the USEPA to assess the risks of lead exposure in children is referred to as the Integrated Exposure Uptake and Biokinetic (IEUBK) model. This model requires as input data on the levels of lead in various environmental media at a specific location, and on the amount of these media contacted by a child living at that location. The inputs to the IEUBK model are selected to reflect estimates of central tendency values (i.e., arithmetic means or medians). These estimated inputs are used to calculate an estimate of the central tendency (the geometric mean) of the distribution of blood lead values that might occur in a population of children exposed to the specified conditions. Assuming the distribution is lognormal, and given (as input) an estimate of the variability between different children (this is specified by the geometric standard deviation or GSD), the model calculates the expected distribution of blood lead values, and estimates the probability that any random child might have a blood lead value over 10 ug/dL.

For this site, two simulations were run using the IEUBK model. The first evaluated risks to a hypothetical nearby resident. The second simulation was used to address the risk observed when the hypothetical residential child engaged in low-intensity recreational activities at the site. By comparing the two simulations and resulting predictions of blood lead concentrations, the excess risk attributable to the low-intensity recreational exposure can be identified.

A detailed printout of the input values used to evaluate lead risks for each scenario is presented in Appendix E. The following sections summarize the input parameters used for these calculations.

Lead Concentration in Soil/Tailings and Intake Assumptions

As discussed previously (Section 3.2.2), background soils were collected from areas surrounding the site. Although the samples do not represent "pristine" (not influenced by human activity) environmental levels, they are thought to be adequate to serve as a potential "off-site" residential concentration. Therefore, these background data were compiled and a value of 64 mg/kg of lead in soil, representing the log-normal UCL95 value was utilized for residential exposure. Intake parameters for the residential scenario were kept as IEUBK model defaults and it was assumed that none of the soil intake was attributable to dust.

The second scenario combined the residential parameters with those for occasional recreational visits. These visitor parameters were based on the average child who is thought to engage in recreational activities 50 days/year and consume 100 mg of soil during each recreational event. Because recreational activities are not thought to occur 365 days/year, a time-weighted approach was used to derive values for input into the IEUBK model. Therefore, if the child visited a site 50 days/year they were exposed to their soil intake at the site on those days. For the remaining 315 days/year the child was assumed to be exposed at home at the concentration specified above. The concentration utilized for recreational exposure was the log-normal UCL95 of the surficial on-site soil and tailings, which was determined to be 1,331 mg/kg. The following table summarizes both intake and concentration parameters for soil/tailings. The weighted average value shows the number input into the IEUBK model for the combined residential/recreational exposure scenario.

Age	Scenario	Days/Year	Intake (mg/day)	Concentration (mg/kg)
0-1	Residential	315	85	64
	Recreational	50	100	1331
	Weighted Average	**365**	**87**	**263**
1-2	Residential	315	135	64
	Recreational	50	100	1331
	Weighted Average	**365**	**130**	**197**
2-3	Residential	315	135	64
	Recreational	50	100	1331
	Weighted Average	**365**	**130**	**197**
3-4	Residential	315	135	64
	Recreational	50	100	1331
	Weighted Average	**365**	**130**	**197**
4-5	Residential	315	100	64
	Recreational	50	100	1331
	Weighted Average	**365**	**100**	**238**
5-6	Residential	315	90	64
	Recreational	50	100	1331
	Weighted Average	**365**	**91**	**254**
6-7	Residential	315	85	64
	Recreational	50	100	1331
	Weighted Average	**365**	**87**	**263**

Water and Air

For this analysis, lead concentrations in water and intake assumptions for each scenario were calculated according to the approach used above for soil/tailings. Residential water concentrations and intakes were set equal to the IEUBK default values. Because the intake rates (5 mL/event) and the site-specific lead concentrations (0.07 ug/L) are so low, the calculated weighted average was the same for the combined residential/recreational scenario as for the residential alone. Therefore, these values were the same in both model simulations.

Lead values for air were kept at the IEUBK default value of 0.1 ug/m^3. This is based on the observation that the maximum lead concentrations in soil/tailing (5,875 mg/kg) would result in a predicted air concentration of 0.03 ug/m^3 using a PEF of 4.6E-9 kg/m3 based on ATV (high intensity) activities. Because this number was lower than the default value, the default was retained in the IEUBK model.

Diet

The default values of lead intake from the diet in the IEUBK model are based on dietary data from 1982 - 1988. Recent FDA data provide strong evidence that concentrations of lead in food have continued to decline since 1988. Based on interpretations of the data, and an extrapolation from the downward trend observed in the 1980's, it has been estimated that the average lead intake from food by children has declined by approximately 30% (Griffin et al., 1999b). Therefore the dietary values were obtained by multiplying the model default values by a factor of 0.70. The resulting values are presented below:

Age (years)	Adjusted Dietary Intake (ug/day)
0-1	3.87
1-2	4.05
2-3	4.54
3-4	4.37
4-5	4.21
5-6	4.44
6-7	4.90

Other

Unlike the residential scenario, average recreational visitors are thought to be exposed to sediments approximately 5 times/year while visiting the site. During each visit, children are assumed to ingest 25 mg of sediment. Based on a log-normal 95UCL lead concentration of 4,446 mg/kg in sediments, this is expected to result in an additional 1.5 ug/day of lead on a yearly basis. Therefore, in the combined residential/recreational scenario, a value of 1.5 ug/day was added to each year of childhood exposure.

Age

Predicted blood lead values were calculated for each scenario (residential & residential + recreational) for a child 0-84 months of age.

Absorption Fraction for Lead in Soil

The absorption fraction is a measure of the amount of metal absorbed from the gastrointestinal tract into the body. This information is especially important for environmental media such as soil or mine wastes, because metals in these media may exist, at least in part, in a variety of poorly water soluble minerals, and may also exist inside particles of inert matrix such as rock or slag. These chemical and physical properties may tend to influence (usually decrease) the absorption (bioavailability) of the metals when ingested. Because no site specific data on bioavailability were available at this site, the default value of 0.60 was used in the model.

GSD

The GSD recommended as the default for the IEUBK model is 1.6 (USEPA 1994). However, several blood lead studies that have been performed in the Salt Lake City area have yielded GSD estimates of about 1.4 (Griffin et al., 1999b). Therefore, values of both 1.6 and 1.4 were evaluated in this assessment.

Results

Using the input parameters identified above, geometric mean blood lead values and P10 values were calculated for both scenarios using the IEUBK model. The results are summarized below:

Scenario	GSD = 1.4		GSD = 1.6	
	Geometric Mean Blood Lead (ug/dL)	P10	Geometric Mean Blood Lead (ug/dL)	P10
Residential Only	1.9	0%	1.9	0.01%
Residential + Low Intensity Recreational	3.8	0.16%	3.8	1.76%

As seen, children who engage in low-intensity recreational activities at this site have higher predicted blood lead levels than those with no recreational exposure. However, the geometric mean values are relatively low and children engaging in recreational activities have under a 5% chance of exceeding a blood lead value of 10 ug/dL using a GSD value of either 1.4 or 1.6.

Based on the results of the IEUBK model, it is considered unlikely that low-intensity recreational exposures to lead in soil/tailings at this site will result in an elevation in blood lead levels which will exceed EPA's guidelines of no more than a 5% chance that a child will have a blood lead value above 10 ug/dL .

6.2.2 Evaluation of Lead Risks to Recreational Teenagers and Adults

The IEUBK model developed by USEPA is intended for evaluation of lead risks to residential children, and is not appropriate for evaluation of lead risks to older children or adults exposed during either low- or high-intensity recreational activities. However, there are several mathematical models which have been proposed for evaluating lead exposure in adults, including those developed by Bowers et al. (1994), O'Flaherty (1993), Leggett (1993), and the State of California (CEPA 1992). Of these, the biokinetic slope factor approach described by Bowers et al. has been identified by USEPA's Technical Workgroup for Lead (USEPA 1996) as a reasonable interim methodology for assessing risks to adults from exposure to lead and for establishing risk-based concentration goals that will protect older children and adults from lead. For this reason, this method was used for estimating risks from soil lead and tailings exposure that could be of concern to older children and adults at this site.

Basic Equation

The Bowers model predicts the blood lead level in an adult exposed to lead in a specified occupational setting by summing the "baseline" blood lead level (PbB_0) (that which would occur in the absence of any above-average site-related exposures) with the increment in blood lead that is expected as a result of increased exposure due to contact with a lead-contaminated site medium. The latter is estimated by multiplying the absorbed dose of lead from site-related exposure by a "biokinetic slope factor" (BKSF). Thus, the basic equation is:

$$PbB = PbB_0 + (PbS \cdot BKSF \cdot IR_s \cdot AF_s \cdot EF_s)/AT$$

where:

PbB = Central estimate of blood lead concentrations (ug/dL) in adults (i.e., women of child-bearing age) that have site exposures to soil lead at concentration, PbS.

PbB_0 = Typical blood lead concentration (ug/dL) in adults (i.e., women of child-bearing age) in the absence of exposures to the site that is being assessed.

BKSF = Biokinetic slope factor relating (quasi-steady state) increase in typical adult blood lead concentration to average daily lead uptake (ug/dL blood lead increase per ug/day lead uptake)

PbS = Soil lead concentration (ug/g) (appropriate average concentration for individual)

IR_s = Intake rate of soil, including both outdoor soil and indoor soil-derived dust (g/day)

AF_s = Absolute gastrointestinal absorption fraction for ingested lead in soil and lead in dust derived from soil (dimensionless). The value of AF_s is given by:

$$AF_s = AF(food) * RBA(soil)$$

EF_s = Exposure frequency for contact with assessed soils (days of exposure during the averaging period)

AT = Averaging time; the total period during which soil contact may occur; 365 days/year for continuing long term exposures.

Once the geometric mean blood lead value is calculated, the full distribution of likely blood lead values in the population of exposed people can then be estimated by assuming the distribution is lognormal with some specified geometric standard deviation (GSD). Specifically, the 95th percentile of the predicted distribution is given by the following equation (Aitchison and Brown 1957):

$$95th = GM \cdot GSD^{1.645}$$

Input values selected for each of these parameters are summarized below:

Parameter	Low Intensity User	High Intensity User	Source
PbB_0 (ug/dL)	1.4	1.4	USEPA (1996) and Based on mean of females age 12-19 and age 20-49 years (Brody et al. 1994)
PbS (ppm)	1331	1331	UCL95 Site lead concentration based on a log-normal distribution
BKSF (ug/dL per ug/day)	0.4	0.4	USEPA (1996)
IR (g/day exposed)	0.025	0.05	Based on intake rate of 25 and 50 mg/day for low and high intensity users, respectively as discussed in Section 5. Multiplied by a factor of 1E-03 g/mg.
EF_s (days exposed/yr)	50	50	Based on exposure assumptions discussed for Non-Lead COPCs
AT (days)	365	365	USEPA (1996)
AF_o (unitless)	0.12	0.12	Based on an absorption factor for soluble lead of 0.20 (USEPA 1996) and a relative bioavailability of 0.6
GSD	1.8	1.8	Based on homogenous population (USEPA 1996)

Results

Based on these input parameters, the predicted geometric mean blood lead and PbB_{95} values for recreational visitors were calculated. For low intensity visitors, the geometric mean blood lead concentration was predicted to be 1.6 ug/dL with a PbB_{95} value of 4.3 ug/dL. In other words, it is predicted that 95% of the low intensity visitors will have a blood lead value less than 4.3 ug/dL. For high intensity visitors, the geometric mean blood lead concentration was predicted to be 1.8 ug/dL with a PbB_{95} value of 4.8 ug/dL. In other words, it is predicted that 95% of the high intensity visitors will have a blood lead value less than 4.8 ug/dL.

The USEPA has not yet issued formal guidance on the blood lead level that is considered appropriate for protecting the health of pregnant women or other adults. However, as noted above, USEPA recommends that there should be no more than a 5% likelihood that a young child should have a PbB value greater than 10 ug/dL (USEPA, 1991b). This same blood lead level (10 ug/dL) is also taken to be the appropriate goal for blood lead levels in the fetus, and hence in pregnant women and women of child-bearing age. Therefore, the health criterion selected for use in this evaluation is that there should be no more than a 5% chance that the blood level of a fetus will be above 10 ug/dL. This health goal is equivalent to specifying that the 95th percentile of the PbB distribution in fetuses does not exceed 10 ug/dL:

$$PbB_{95}\text{fetal} \leq 10 \text{ ug/dL}$$

The relationship between fetal and maternal blood lead concentration has been investigated in a number of studies. Goyer (1990) reviewed a number of these studies, and concluded that there was no significant placental/fetal barrier for lead, with fetal blood lead values being equal to or just slightly less than maternal blood lead values. The mean ratio of fetal PbB to maternal PbB in three recent studies cited by Goyer was 0.90. Based on this, the 95th percentile PbB in the mother is then:

$$PbB_{95}maternal = 10/0.90 = 11.1 \text{ ug/dL}.$$

That is, the target blood lead level for pregnant women is estimated to be 11.1 ug/dL. Because individuals in the recreational population are assumed to be mainly age 12-49, it is possible that women of child-bearing age may also be included in this group, so the same target blood lead value is assumed to apply to this population as well.

A comparison of the 95th percentile blood lead levels predicted for site recreational visitors shows that recreational use at this site is not predicted to result in blood lead levels which exceed a target concentration of 11.1 ug/dL.

6.3 Uncertainties

It is important to recognize that the exposure and risk calculations presented in this document are based on a number of assumptions, and that these assumptions introduce uncertainty into the exposure and risk estimates. Assumptions are required because of data gaps in our understanding of the toxicity of chemicals, and in our ability to estimate the true level of human exposure to chemicals. In most cases, assumptions employed in the risk assessment process to deal with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate rather than an underestimate of risk. It is important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site.

6.3.1 Uncertainty in Lead Concentration Estimates

Evaluation of human health risk at any particular location requires accurate information on the average concentration level of a COPC at that location. However, concentration values may vary from sample to sample, so the USEPA recommends that the 95% upper confidence limit of the mean be used in evaluation of both average and RME exposure and risk. This approach typically ensures that all of the risk estimates are more likely to be high than low.

Risks from exposure to lead were evaluated based on surficial soil data. This decision was based on the assumptions that recreational users be most likely to be exposed to surficial soils based on their activities. Based on the depth distribution observed for lead, risks from exposure to subsurface soils will be similar or less than those observed for surface soils. However, if concentrations for lead are ever found to increase as a function of depth, the risks based on surface soil exposure will underestimate risks for those individuals exposed to buried materials. The maximum lead concentration in soil/tailings observed at the site at any depth is 21,380 mg/kg.

6.3.2 Uncertainty in Lead Absorption from Soil

Another important source of uncertainty regarding the risk from lead in soil is the degree of absorption (RBA) within the gastrointestinal tract. For this risk assessment, a default relative bioavailability factor for lead of 0.60 has been applied. This introduces uncertainty because the selected value is not based on actual measurements for site soils. Soils are complex by nature and may have numerous attributes which influence

overall absorptions characteristics.

6.3.3 Uncertainty in Modeling Approach

All predictive models, including the IEUBK model and the ISE model, are subject to a number of limitations. First, there is inherent difficulty in providing the models with reliable estimates of human exposure to lead-contaminated media. For example, exposure to soil and dust is difficult to quantify because human intake of these media is likely to be highly variable, and it is very difficult to derive accurate measurements of actual intake rates. Second, it is often difficult to obtain reliable estimates of key pharmacokinetic parameters in humans (e.g., absorption fraction, distribution and clearance rates), since direct observations in humans are limited. Finally, the absorption, distribution and clearance of lead in the human body is an extremely complicated process, and any mathematical model intended to simulate the actual processes is likely to be an over-simplification. Consequently, model calculations and predictions are generally rather uncertain.

The Bowers model used to assess lead exposures in youths and adults requires a composite toxicokinetic parameter (the biokinetic slope factor) to predict the effect of exposure on blood lead levels. This value is derived mainly from studies in adult males, and it is not certain that the value is accurate for youths or for women (especially pregnant women). Also, the exposures being modeled with the Bowers model are intermittent rather than continuous, so blood lead levels in the exposed populations are expected to show temporal variability. Toxicity data are not adequate to estimate the level of health risk associated with occasional (rather than continuous) elevations in blood lead level due to intermittent exposures to elevated lead levels in the environment. However, since the observed lead levels in soil/tailings result in predicted blood lead levels that are well below the established level of concern, these uncertainties in the modeling approach do not cast serious doubt on the accuracy of the conclusion that lead levels at this site are not of concern to older children or adults.

7.0 SUMMARY AND CONCLUSIONS

7.1 Risks from Non-Lead COPCs

Interpretation of risk characterization results is a matter of judgement by the risk manager. The measure used to describe the potential for noncarcinogenic toxicity to occur in an individual is expressed by comparing an exposure level over a specified time period with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is referred to as a hazard quotient. To assess the overall potential for noncarcinogenic effects posed by more than one chemical, these HQs are summed to obtain a hazard index. In general , USEPA considers that acceptable level of excess risk under RME assumptions is an HI equal to or less than one (1E+00) for non-cancer risks. In this case, it is believed that there is no appreciable risk that noncancer health effects will occur. If an HI exceeds 1E+00, there is some possibility that noncancer effects may occur, although an HI above 1E+00 does not indicate an effect will definitely occur. In this instance, it is important to review the contribution of risks from the individual chemicals which were evaluated in the risk assessment.

In evaluating carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The level of total cancer risk that is of concern is a matter of personal, community and regulatory judgement. In general, it is the policy of the USEPA that remedial action is not warranted where excess cancer risks to the RME individual do not exceed a level of 1E-04 (USEPA, 1991b). It should be noted that, the upper boundary of the risk range is not a discrete line at 1E-04. This risk level may be considered acceptable if justified based on site-specific conditions. However, a risk manager may also decide that a lower level of risk to human health is unacceptable and that remedial action is warranted where, for example, there are uncertainties in the risk assessment results.

A summary of the estimated non-cancer and cancer risks resulting from exposure to arsenic at this site is presented below.

Endpoint	Population	Average	RME
Non-Cancer	*Total Risk Low Intensity User*	*2.4E-02*	*9.3E-02*
	Total Risk High Intensity User	*1.4E-02*	*5.8E-02*
Cancer Risk	*Total Risk Low Intensity User*	*1.8E-06*	*2.2E-05*
	Total Risk High Intensity User	*8.1E-07*	*1.1E-05*

As seen, none of the non-cancer risks are predicted to exceed a Hazard Index of 1.0. Additionally, no cancer risks are predicted to fall within or below the USEPA's acceptable risk range of 1E-04 and 1E-06. These results indicate that exposure to arsenic is resulting in unacceptable levels of health risk to either low-intensity or high-intensity recreational visitors at this site.

7.2 Risks from Lead

The IEUBK model was utilized to predict the geometric mean blood lead values and P10 values for children exposed either just residential or via a combination of residential and recreational exposure. This approach was used in order to determine the excess blood lead levels attributable to any recreational activities engaged in at this site. The geometric mean blood lead values were predicted to be 1.9 and 3.8 ug/dL for residential and residential

plus recreational scenarios, respectively. Although the addition of recreational exposure into the IEUBK model results in higher blood lead levels, the P10 values under this scenario are below EPA's guideline of 5% and are predicted to range from 0.16% (GSD=1.4) to 1.8% (GSD=1.6), depending on the GSD selected. These results indicate that low-intensity recreational exposures at this site are unlikely to result in blood lead levels in children which result in greater than a 5% probability of exceeding a blood lead level of 10 ug/dL.

The Bowers model was utilized to predict the geometric mean and 95th Percentile blood lead concentrations (PbB_{95}) in visitors who may engage at recreational activities at the site. The predicted geometric mean blood lead values were found to range be 1.6 and 1.8 ug/dL, for low intensity and high intensity recreational visitors, respectively. The PbB_{95} concentrations were found to be 4.3 and 4.8 ug/dL for low and high intensity recreational visitors, indicating that recreational activities at the site will not result in blood lead levels with a greater than 5% probability of exceeding a blood lead level of 10 ug/dL.

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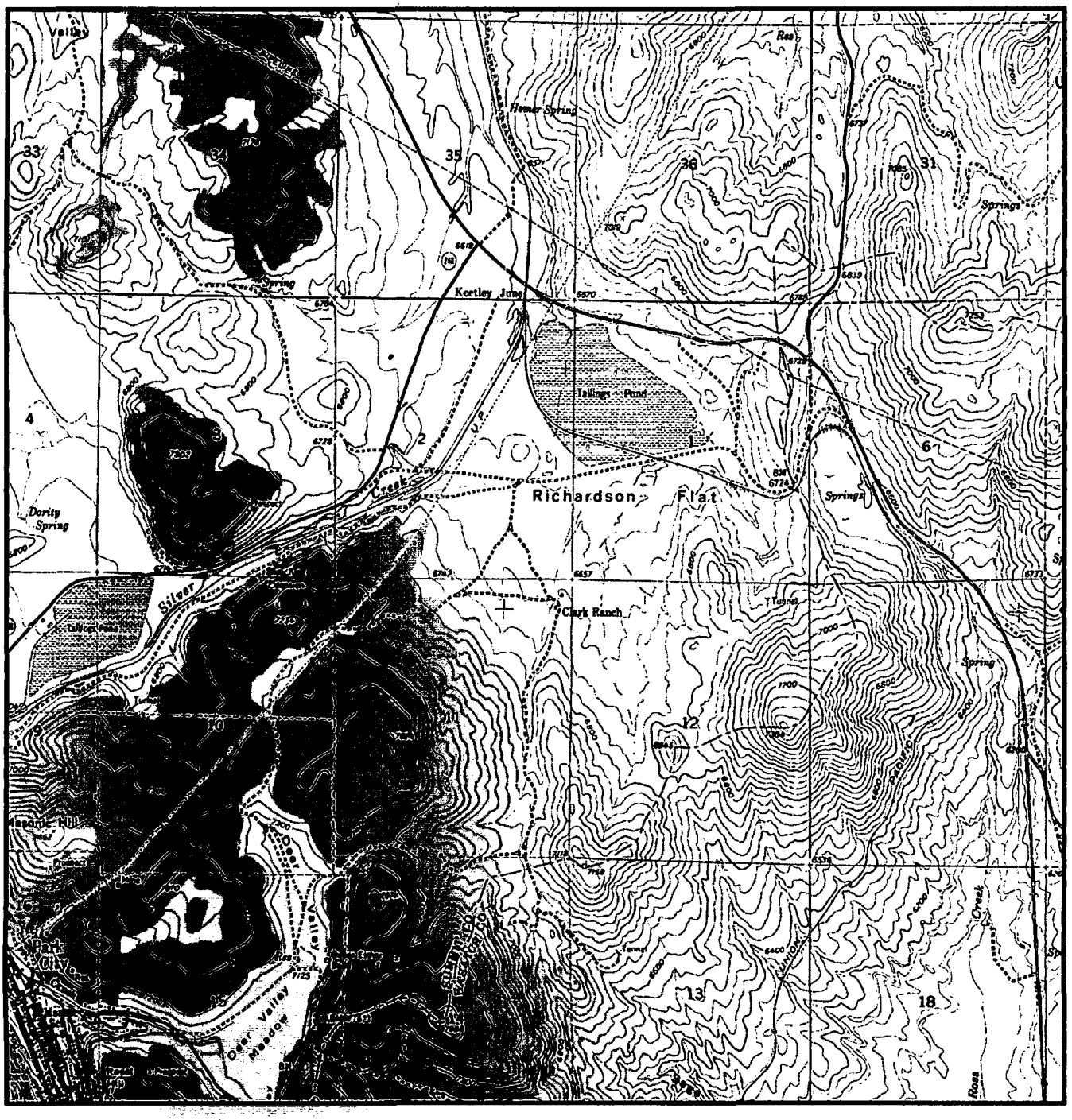

Figure 1 - 1
Richardson Flat Tailings Site Location Map

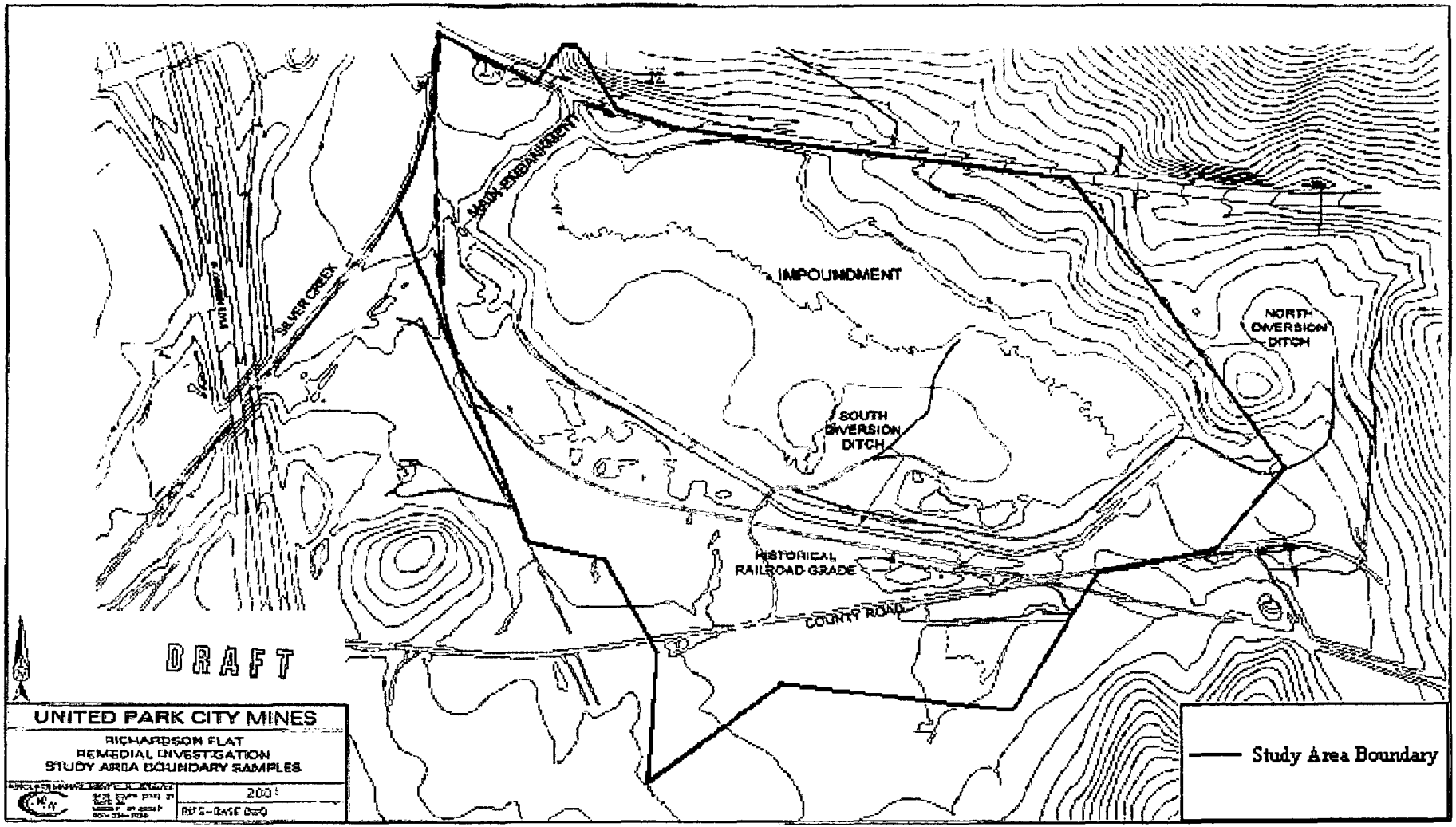

Figure 3-1
Richardson Flats Tailings Study Area Boundary

Source: RMC, 2001 [DRAFT RI/FS]

Figure 4-1: Conceptual Site Model for Recreational Exposure to COPCs

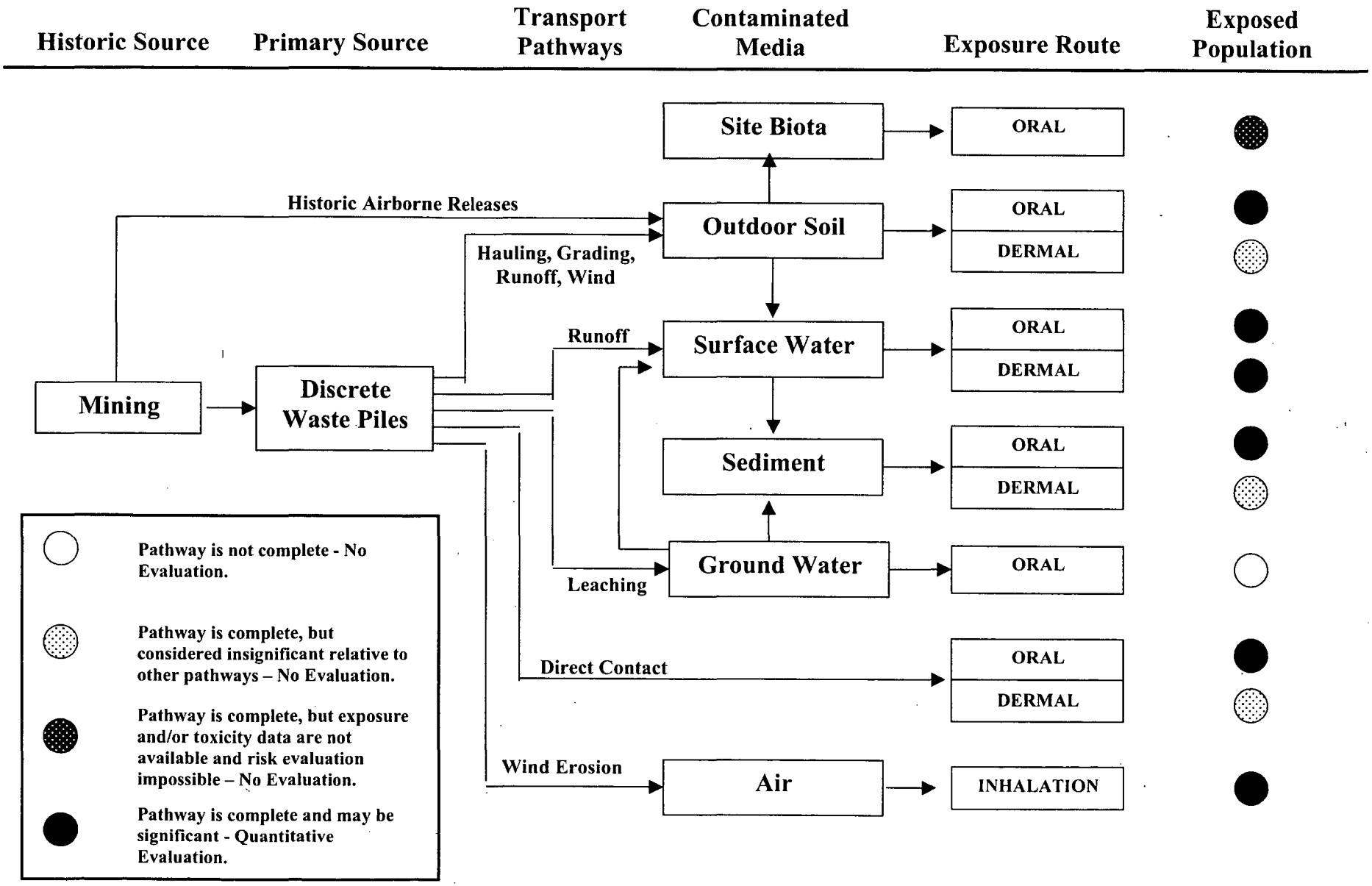

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Table 3-1
Summary of Analytical Parameters Across Media Types and Sampling Programs

Analytes	Tailings	Soil			Sediment	Groundwater		Surface Water	
		Background	Off-Impoundment	On-Impoundment		Dissolved	Total	Dissolved	Total
Aluminum	2	NONE	NONE	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6	1; 3; 2; 5; 6
Antimony	2	NONE	NONE	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 6	1; 3; 2; 6
Arsenic	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Barium	NONE	2	2	2; 3	3	3; 7	3; 7	5; 6; 7	3; 5; 7
Beryllium	NONE	NONE	NONE	3	3	3; 7	3; 7	NONE	3
Boron	NONE	NONE	NONE	NONE	NONE	NONE	NONE	5	NONE
Cadmium	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Calcium	NONE	NONE	NONE	3	3	3; 7	2; 3; 7	5; 6	1; 2; 3; 6
Chromium	2	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Cobalt	NONE	NONE	NONE	3	3	3; 7	3; 7;	NONE	3
Copper	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Cyanide	NONE	NONE	NONE	NONE	NONE	NONE	7	NONE	5; 6
Iron	2	NONE	NONE	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6	1; 2; 3; 5; 6
Lead	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Magnesium	NONE	NONE	NONE	3	3	3; 7	2; 3; 7	5; 6	1; 2; 3; 6
Manganese	NONE	NONE	NONE	3	3	2; 3; 7	2; 3; 7	1; 2; 5; 6	1; 2; 3; 5; 6
Mercury	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Nickel	NONE	NONE	NONE	3	3	3; 7	3; 7	NONE	3
Phosphorus	NONE	NONE	NONE	NONE	NONE	NONE	2	5	2; 5
Potassium	NONE	NONE	NONE	3	3	3; 7	2; 3; 7	5	1; 2; 3; 6
Selenium	2	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Silver	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 2; 3; 5; 6; 7
Sodium	NONE	NONE	NONE	3	3	2; 3; 7	2; 3; 7	5	1; 2; 3; 6
Thallium	NONE	NONE	NONE	3	3	3; 7	3; 7	NONE	3
Vanadium	NONE	NONE	NONE	3	3	3; 7	3; 7	NONE	3
Zinc	2; 4	2	2	2; 3	1; 2; 3	2; 3; 7	2; 3; 7	1; 2; 5; 6; 7	1; 3; 5; 6; 7

Key to Sources
1 = USEPA (2001a) Watershed Study
2 = RMC (2001c) Monthly Monitoring Data
3 = E&E (1993)
4 = USEPA (1991)
5 = STORET
6 = UPCM
7 = RMC (2000a)

Table 3-2: Summary Statistics

Part A: Sediment

Parameter	Detection Frequency	Min* (mg/kg)	Max* (mg/kg)	Avg* (mg/kg)
Aluminum	12/12 (100%)	1,930	28,800	11,844
Antimony	12/12 (100%)	36	99	75
Arsenic	12/12 (100%)	101	310	162
Barium	5/5 (100%)	92	562	276
Beryllium	5/5 (100%)	1.1	2.3	1.8
Cadmium	12/12 (100%)	18	93	52
Calcium	5/5 (100%)	39,800	96,000	58,780
Chromium	12/12 (100%)	15	62	26
Cobalt	5/5 (100%)	5.8	20	14
Copper	12/12 (100%)	173	725	301
Iron	12/12 (100%)	23,000	91,900	39,083
Lead	12/12 (100%)	1,880	6,520	3,453
Magnesium	5/5 (100%)	10,900	14,100	12,960
Manganese	5/5 (100%)	2,200	42,000	10,938
Mercury	12/12 (100%)	0.32	8.2	2.3
Nickel	5/5 (100%)	13	97	45
Potassium	5/5 (100%)	886	4,760	2,847
Selenium	8/12 (67%)	2.5	43	10
Silver	12/12 (100%)	8.0	41	19
Sodium	5/5 (100%)	206.0	1,150.0	603.4
Thallium	5/5 (100%)	6.6	14	8.6
Vanadium	5/5 (100%)	9.5	71	38
Zinc	12/12 (100%)	2,940	15,200	8,945

Part B: Surface Water

Parameter	Detection Frequency	Min* (ug/L)	Max* (ug/L)	Avg* (ug/L)
Aluminum	40/125 (32%)	0.01	1.4	0.07
Ammonia	34/41 (83%)	0.05	0.97	0.30
Antimony	46/109 (42%)	0.003	0.04	0.006
Arsenic	81/246 (33%)	0.003	0.75	0.009
Barium	108/109 (99%)	0.02	0.26	0.08
Beryllium	5/5 (100%)	0.001	0.003	0.002
Boron	1/1 (100%)	0.06	0.06	0.06
Cadmium	92/224 (41%)	0.001	0.01	0.002
Calcium	143/143 (100%)	39	404	174
Chlorine	67/67 (100%)	30	269	102
Chromium	19/230 (8%)	0.003	0.05	0.007
Chromium, hexavalent	1/1 (100%)	0.001	0.001	0.001
Cobalt	1/5 (20%)	0.003	0.01	0.004
Copper	45/235 (19%)	0.003	0.39	0.009
Cyanide	22/121 (18%)	0.002	0.05	0.004
Iron	101/189 (53%)	0.003	30	0.34
Lead	243/427 (57%)	0.002	26	0.13
Magnesium	140/140 (100%)	9.1	90	42
Manganese	355/356 (100%)	0.003	61	1.4
Mercury	41/326 (13%)	1.0.E-07	2.1	0.01
Nickel	2/5 (40%)	0.01	0.02	0.01
Phosphorus	74/129 (57%)	0.01	0.74	0.04
Potassium	86/130 (66%)	0.25	6.2	2.3
Selenium	23/232 (10%)	0.001	0.02	0.002
Silica	1/1 (100%)	13	13	13
Silver	5/230 (2%)	0.001	0.05	0.003
Sodium	130/130 (100%)	6.7	177	55
Thallium	0/5 (0%)	0.001	0.001	0.001
Vanadium	0/5 (0%)	0.02	0.02	0.02
Zinc	274/276 (99%)	0.01	96	1.3

Part C: Soil and Tailings

Parameter	Detection Frequency	Min* (mg/kg)	Max* (mg/kg)	Avg* (mg/kg)
Arsenic	59/64 (92%)	2.5	243	41
Barium	16/16 (100%)	175	365	241
Cadmium	8/17 (47%)	0.25	96	9.1
Chromium	16/16 (100%)	16	33	22
Copper	18/18 (100%)	13	336	64
Lead	62/62 (100%)	14	5,875	661
Mercury	4/16 (25%)	0.05	3.2	0.32
Selenium	0/16 (0%)	2.5	2.5	2.5
Silver	1/17 (6%)	2.5	22.1	3.7
Zinc	18/18 (100%)	47	14,100	1,378

* Non-Detects evaluated at 1/2 the Detection limit

Table 3-3: Evaluation of Beneficial and Essential Minerals

PART A: EVALUATION OF BENEFICIAL AND ESSENTIAL MINERALS IN SEDIMENT

Chemical	Max Conc[a] mg/kg	TWA-Intake[b] kg/kg-day	Max DI[c] mg/kg-day	RDA[d] mg/kg-day	Ratio DI/RDA	Retain
Calcium	96,000	2.60E-08	2.50E-03	14	<0.001	NO
Chromium III	62	2.60E-08	1.62E-06	1	<0.001	NO
Cobalt	20	2.60E-08	5.20E-07	0.06	<0.001	NO
Copper	725	2.60E-08	1.89E-05	0.037	<0.001	NO
Iron	91,900	2.60E-08	2.39E-03	0.3	0.009	NO
Magnesium	14,100	2.60E-08	3.67E-04	5.7	<0.001	NO
Manganese	42,000	2.60E-08	1.09E-03	0.005	0.218	NO
Potassium	4,760	2.60E-08	1.24E-04	0.57	<0.001	NO
Selenium	43	2.60E-08	1.12E-06	0.005	<0.001	NO
Sodium	1,150	2.60E-08	2.99E-05	34	<0.001	NO
Zinc	15,200	2.60E-08	3.95E-04	0.30	0.001	NO

PART B: EVALUATION OF BENEFICIAL AND ESSENTIAL MINERALS IN SURFACE WATER

Chemical	Max Conc[a] ug/L	TWA-Intake[b] kg/kg-day	Max DI[c] mg/kg-day	RDA[d] mg/kg-day	Ratio DI/RDA	Retain
Calcium	404	3.54E-05	1.43E-02	14	0.001	NO
Chromium III	0.05	3.54E-05	1.77E-06	1	<0.001	NO
Chloride	325	3.54E-05	1.15E-02	0.51	0.023	NO
Cobalt	0.01	3.54E-05	3.68E-07	0.06	<0.001	NO
Copper	0.39	3.54E-05	1.38E-05	0.037	<0.001	NO
Flouride	0.31	3.54E-05	1.10E-05	0.060	<0.001	NO
Iron	30	3.54E-05	1.06E-03	0.3	0.004	NO
Magnesium	90	3.54E-05	3.19E-03	5.7	<0.001	NO
Manganese	61	3.54E-05	2.16E-03	0.005	0.432	NO
Phosphorus	0.74	3.54E-05	2.62E-05	14.000	<0.001	NO
Potassium	6.2	3.54E-05	2.19E-04	0.57	<0.001	NO
Selenium	0.02	3.54E-05	6.02E-07	0.005	<0.001	NO
Sodium	177	3.54E-05	6.27E-03	34	<0.001	NO
Zinc	96	3.54E-05	3.40E-03	0.30	0.011	NO

PART C: EVALUATION OF BENEFICIAL AND ESSENTIAL MINERALS IN SOIL AND TAILINGS

Chemical	Max Conc[a] mg/kg	TWA-Intake[b] kg/kg-day	Max DI[c] mg/kg-day	RDA[d] mg/kg-day	Ratio DI/RDA	Retain
Chromium III	33	5.20E-07	1.72E-05	1	<0.001	NO
Copper	336	5.20E-07	1.75E-04	0.037	0.005	NO
Selenium	2.5	5.20E-07	1.30E-06	0.005	<0.001	NO
Zinc	14,100	5.20E-07	7.33E-03	0.30	0.024	NO

[a] Maximum detected concentration

[b] TWA-Intake = Time-weight average intake rate of environmental medium (RME Resident)

Soil: Assumes ingestion of 200 mg/d for 6 years (as 15 kg child) and 100 mg/d for 24 years (as 70 kg adult) for 350 days/yr

Water: Assumes ingestion of 1 L/d for 6 years (as 15 kg child) and 2 L/d for 24 years (as 70 kg adult) for 350 days/yr

[c] DI = Daily intake of chemical (mg/kg-day)

[d] RDA = Recommended Dietary Allowance or Toxicity Value from USEPA (1994)

Sodium value based on 2,400 mg/day recommended daily allowance divided by 70 kg body weight

Table 3-4: Comparison of Detection Limits to Risk Based Concentrations

Part A: Sediment

Parameter	Detection Frequency	Non-Detect Range (ppm)	RBC (ppm)	DL Adequate?	Retain?
Aluminum	12/12 (100%)	--	7,800	YES	**YES**
Antimony	12/12 (100%)	--	3.1	YES	**YES**
Arsenic	12/12 (100%)	--	0.04	YES	**YES**
Barium	5/5 (100%)	--	550	YES	**YES**
Beryllium	5/5 (100%)	--	16	YES	**YES**
Cadmium	12/12 (100%)	--	7.8	YES	**YES**
Lead	12/12 (100%)	--	400	YES	**YES**
Mercury	12/12 (100%)	--	2.2	YES	**YES**
Nickel	5/5 (100%)	--	160	YES	**YES**
Silver	12/12 (100%)	--	39	YES	**YES**
Thallium	5/5 (100%)	--	0.55	YES	**YES**
Vanadium	5/5 (100%)	--	55	YES	**YES**

Part B: Surface Water

Parameter	Detection Frequency	Non-Detect Range (ppm)	RBC (ppm)	DL Adequate?	Retain?
Aluminum	40/125 (32%)	0.0171 - 0.05	3,700	YES	**YES**
Ammonia	34/41 (83%)	0.1	21	YES	**YES**
Antimony	46/109 (42%)	0.005 - 0.0243	1.5	YES	**YES**
Arsenic	77/228 (34%)	0.005 - 0.02	0.45	YES	**YES**
Barium	108/109 (99%)	0.1	260	YES	**YES**
Beryllium	5/5 (100%)	--	7.3	YES	**YES**
Boron	1/1 (100%)	--	329	YES	**YES**
Cadmium	92/224 (41%)	0.001 - 0.005	1.8	YES	**YES**
Chlorine	67/67 (100%)	--	0.04	YES	**YES**
Chromium VI	1/1 (100%)	--	11	YES	**YES**
Cyanide	22/121 (18%)	0.004 - 0.008	73	YES	**YES**
Lead	236/409 (58%)	0.003 - 0.1	4.0	YES	**YES**
Mercury	41/326 (13%)	0.0000002 - 0.005	1.1	YES	**YES**
Nickel	2/5 (40%)	0.0111	73	YES	**YES**
Silica	1/1 (100%)	--		YES	**YES**
Silver	5/230 (2%)	0.002 - 0.1	18	YES	NO
Thallium	0/5 (0%)	0.0016	0.26	YES	NO
Vanadium	0/5 (0%)	0.0357	26	YES	NO

Part C: Soil and Tailings

Parameter	Detection Frequency	Non-Detect Range (ppm)	RBC (ppm)	DL Adequate?	Retain?
Arsenic	59/64 (92%)	5	0.04	YES	**YES**
Barium	16/16 (100%)	--	550	YES	**YES**
Cadmium	8/17 (47%)	0.5	7.8	YES	**YES**
Lead	62/62 (100%)	--	400	YES	**YES**
Mercury	4/16 (25%)	0.1	2.2	YES	**YES**
Silver	1/17 (6%)	5	39	YES	**YES**

[+] Based on Region 9 PRG value for tap water

Table 3-5: Maximum and Average Chemical Concentrations in Soil and Background Concentrations in the United States

Chemical	Max Soil Conc (mg/kg)	Avg Soil Conc (mg/kg)	Background Concentrations for Soils in the Western United States*		Background Concentrations for Soils in the United States**	Background Concentrations for Soils in the United States***		Retain?
			Range (ppm)	Geometric Mean	Range (ppm)	Range (ppm)	Mean	
Arsenic	243	41	<0.10 - 97	5.5	1.0 - 40	1 - 40	5.0	**YES**
Barium	365	241	70 - 5,000	580	100 - 3,500	15 - 3,000		NO
Cadmium	96	9.1	<150 - 300	65	0.01 - 7.0		0.25	**YES**
Lead	5,875	661	<10 - 700	17	2.0 - 200			**YES**
Mercury	3.2	0.32	<0.01 - 4.6	0.05	0.01 - 0.08	0.02 - 0.625		**YES**
Silver	22.1	3.7			0.1 - 5.0			**YES**

* Based on Shacklette and Boerngen, 1984

** Based on Dragun, 1988

*** Based on ATSDR, 1997

Table 3-6: Maximum Chemical Concentrations and Risk-Based Concentrations for Recreational Users

Part A: Sediment

Chemical	Max Sediment Conc (mg/kg)	Calculated RBC	Retain as COPC?
Aluminum	28,800	3,832,463	NO
Antimony	99	1,533	NO
Arsenic	310	75	**YES**
Barium	562	268,275	NO
Beryllium	2.3	7,665	NO
Cadmium	93	3,832.5	NO
Lead	6,520	400	**YES**
Manganese	42,000	536,550	NO
Mercury	8.2	1,150	NO
Nickel	97	76,650	NO
Silver	41	19,163	NO
Thallium	13.6	307	NO
Vanadium	71	34,493	NO

Part B: Surface Water

Chemical	Max Surface Water Conc (ug/L)	Calculated RBC	Retain as COPC?
Aluminum	1.4	3,276	NO
Ammonia	0.97	21*	NO
Antimony	0.04	1310	NO
Arsenic	0.8	0.06	**YES**
Barium	0.26	229,297	NO
Beryllium	0.003	6551	NO
Boron	0.06	294808	NO
Cadmium	0.01	3,276	NO
Chlorine	269	327,564	NO
Chromium VI	0.001	9827	NO
Cyanide	0.05	65513	NO
Lead	26	4.0	**YES**
Mercury	2.1	983	NO
Nickel	0.02	65,513	NO

Part C: Soil and Tailings

Chemical	Max Soil/Tailing Conc (mg/kg)	Calculated RBC		Minimum Calculated RBC	Retain as COPC?
		RME low-intensity visitor	RME high-intensity visitor		
Arsenic	243	71.9	95.8	71.9	**YES**
Cadmium	96	191.6	255.5	191.6	NO
Lead	5,875	400		400	**YES**
Mercury	3	57.5	77	57.5	NO
Silver	22	4E+07	5E+07	4E+07	NO

* Based on HQ = 0.1 or Risk = 1E-06

APPENDIX A

RAW DATA SUMMARY

electronic data will be provided upon request

APPENDIX B

RBC CALCULATIONS

RBCs were calculated for use in the COPC screening process using intake parameters for the RME exposure scenarios developed in the Draft Exposure Assumptions document for this site (attached in this appendix for convenience). RBCs for sediment, surface water and soil/tailings are based on the most stringent concentration calculated for RME (high and low intensity) visitors for ingestion of each media. The RBC for air is based on inhalation of estimated airborne concentrations due to disturbance of soil/tailings. RfDs, RfCs, and slope factors used in RBC calculations are based on the Region 3 RBC Table and the online IRIS database. RBCs are based on Target Risk levels of 1E-06 for carcinogenic chemicals and a hazard quotient (HQ) of 0.1 for noncarcinogenic chemicals. Table B-1 shows all of the values used to calculate the RBC values used in the COPC selection process.

Table B-1: RBC Calculations

Soil/Tailing

Low Intensity User

Part A: EVALUATION OF CHRONIC NONCANCER RISK

				RME		
	PRG	HIFs	RBAs	DIs	RfD	HQ
Analyte	mg/kg	kg/kg-d	--	mg/kg-d	mg/kg-d	--
Arsenic	71.86	5.22E-07	0.80	3.00E-05	3.00E-04	1.000E-01
Cadmium	191.63	5.22E-07	1.00	1.00E-04	1.00E-03	1.000E-01
Mercury	57.49	5.22E-07	1.00	3.00E-05	3.00E-04	1.000E-01
Silver	40379305	5.22E-07	1.00	2.11E+01	5.0E-03	1.000E-01

Part B: EVALUATION OF CANCER RISK

	PRG	HIFs	RBAs	DIs	SF	Risk
Analyte	mg/kg	kg/kg-d	--	mg/kg-d		--
Arsenic	3.73	2.24E-07	0.80	6.67E-07	1.50E+00	1.000E-06

High Intensity User

Part A: EVALUATION OF CHRONIC NONCANCER RISK

				RME		
	PRG	HIFs	RBAs	DIs	RfD	HQ
Analyte	mg/kg	kg/kg-d	--	mg/kg-d	mg/kg-d	--
Arsenic	95.81	3.91E-07	0.80	3.00E-05	3.00E-04	1.000E-01
Cadmium	255.50	3.91E-07	1.00	1.00E-04	1.00E-03	1.000E-01
Mercury	76.65	3.91E-07	1.00	3.00E-05	3.00E-04	1.000E-01
Silver	53839601	3.91E-07	1.00	2.11E+01	5.0E-03	1.000E-01

Part B: EVALUATION OF CANCER RISK

Analyte	PRG mg/kg	HIFs kg/kg-d	RBAs --	DIs mg/kg-d	SF	Risk --
Arsenic	6.21	0.00E+00	0.80	0.00E+00	1.50E+00	0.000E+00

Sediment

Part A: EVALUATION OF CHRONIC NONCANCER RISK

Analyte	PRG mg/kg	HIFs kg/kg-d	RBAs --	RME DIs mg/kg-d	RfD mg/kg-d	HQ --
Aluminum	3832463.36	2.61E-08	1.00	1.00E-01	1.00E+00	1.000E-01
Antimony	1533.00	2.61E-08	1.00	4.00E-05	4.00E-04	1.000E-01
Arsenic	1437.19	2.61E-08	0.80	3.00E-05	3.00E-04	1.000E-01
Barium	268275.00	2.61E-08	1.00	7.00E-03	7.00E-02	1.000E-01
Beryllium	7665.00	2.61E-08	1.00	2.00E-04	2.00E-03	1.000E-01
Cadmium	3832.50	2.61E-08	1.00	1.00E-04	1.00E-03	1.000E-01
Manganese	536550.00	2.61E-08	1.00	1.40E-02	1.40E-01	1.000E-01
Mercury	1149.75	2.61E-08	1.00	3.00E-05	3.00E-04	1.000E-01
Nickel	76650.00	2.61E-08	1.00	2.00E-03	2.00E-02	1.000E-01
Silver	19162.69	2.61E-08	1.00	5.00E-04	5.00E-03	1.000E-01
Thallium	306.60	2.61E-08	1.00	8.00E-06	8.00E-05	1.000E-01
Vanadium	34492.50	2.61E-08	1.00	9.00E-04	9.00E-03	1.000E-01

Part B: EVALUATION OF CANCER RISK

Analyte	PRG mg/kg	HIFs kg/kg-d	RBAs --	DIs mg/kg-d	SF	Risk --
Arsenic	74.55	1.12E-08	0.80	6.67E-07	1.50E+00	1.000E-06

WATER

Part A: EVALUATION OF CHRONIC NONCANCER RISK

Analyte	PRG mg/L	HIFs L/kg-d	RBAs --	RME DIs mg/kg-d	RfD mg/kg-d	HQ --
Aluminum	3275.641026	3.05E-05	1.00	1.00E-01	1.00E+00	1.000E-01
Ammonia		3.05E-05	1.00	0.00E+00		#DIV/0!
Antimony	1.31	3.05E-05	1.00	4.00E-05	4.00E-04	1.000E-01
Arsenic	1.23	3.05E-05	0.80	3.00E-05	3.00E-04	1.000E-01
Barium	229.30	3.05E-05	1.00	7.00E-03	7.00E-02	1.000E-01

Beryllium	6.55	3.05E-05	1.00	2.00E-04	2.00E-03	1.000E-01
Boron	294.81	3.05E-05	1.00	9.00E-03	9.00E-02	1.000E-01
Cadmium	3.28	3.05E-05	1.00	1.00E-04	1.00E-03	1.000E-01
Chlorine1	327.56	3.05E-05	1.00	1.00E-02	1.00E-01	1.000E-01
Chromium VI	9.83	3.05E-05	1.00	3.00E-04	3.00E-03	1.000E-01
Cyanide	65.51	3.05E-05	1.00	2.00E-03	2.00E-02	1.000E-01
Mercury	0.98	3.05E-05	1.00	3.00E-05	3.00E-04	1.000E-01
Nickel	65.51	3.05E-05	1.00	2.00E-03	2.00E-02	1.000E-01

Part B: EVALUATION OF CANCER RISK

	PRG	HIFs	RBAs	DIs	SF	Risk
Analyte	**mg/L**	**L/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	0.06	1.31E-05	0.80	6.67E-07	1.50E+00	1.00E-06

Air (From Soil/Tailing)

Low Intensity User

Part A: EVALUATION OF CHRONIC NONCANCER RISK

				RME		
	PRG	HIFs	RBAs	DIs	RfC	HQ
Analyte	**mg/m3**	**m3/kg-d**	**--**	**mg/kg-d**	**mg/kg-d**	**--**
Arsenic		3.34E-02	0.80	0.00E+00	--	
Barium	0.0004	3.34E-02	1.00	1.40E-05	1.40E-04	1.000E-01
Cadmium	0.0002	3.34E-02	1.00	5.70E-06	5.70E-05	1.000E-01
Chromium III		3.34E-02	1.00	0.00E+00	--	
Chromium VI	0.00004	3.34E-02	2.00	3.00E-06	3.00E-05	1.000E-01
Copper		3.34E-02	1.00	0.00E+00	--	
Mercury	0.0003	3.34E-02	1.00	8.60E-06	8.60E-05	1.000E-01
Selenium		3.34E-02	1.00	0.00E+00	--	
Silver		3.34E-02	1.00	0.00E+00	--	
Zinc		3.34E-02	1.00	0.00E+00	--	

Part B: EVALUATION OF CANCER RISK

	PRG	HIFs	RBAs	DIs	SF	Risk
Analyte	**mg/m3**	**m3/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	0.00002	1.43E-02	0.80	2.33E-07	4.30E+00	1.000E-06
Cadmium	0.00004	1.43E-02	1.00	5.56E-07	1.80E+00	1.000E-06
Chromium VI	0.006	1.43E-02	1.00	8.33E-05	1.20E-02	1.000E-06

High Intensity User

Part A: EVALUATION OF CHRONIC NONCANCER RISK

Analyte	PRG mg/m3	HIFs m3/kg-d	RBAs --	RME DIs mg/kg-d	RfC mg/kg-d	HQ --
Arsenic		2.35E-02	0.80	0.00E+00	--	
Barium	0.0006	2.35E-02	1.00	1.40E-05	1.40E-04	1.000E-01
Cadmium	0.0002	2.35E-02	1.00	5.70E-06	5.70E-05	1.000E-01
Chromium III		2.35E-02	1.00	0.00E+00	--	
Chromium VI	0.00006	2.35E-02	2.00	3.00E-06	3.00E-05	1.000E-01
Copper		2.35E-02	1.00	0.00E+00	--	
Mercury	0.0004	2.35E-02	1.00	8.60E-06	8.60E-05	1.000E-01
Selenium		2.35E-02	1.00	0.00E+00	--	
Silver		2.35E-02	1.00	0.00E+00	--	
Zinc		2.35E-02	1.00	0.00E+00	--	

Part B: EVALUATION OF CANCER RISK

Analyte	PRG mg/m3	HIFs m3/kg-d	RBAs --	DIs mg/kg-d	SF	Risk --
Arsenic	0.00004	8.05E-03	0.80	2.33E-07	4.30E+00	1.000E-06
Cadmium	0.00007	8.05E-03	1.00	5.56E-07	1.80E+00	1.000E-06
Chromium VI	0.010	8.05E-03	1.00	8.33E-05	1.20E-02	1.000E-06

DRAFT

EXPOSURE ASSUMPTIONS
RICHARDSON FLATS TAILING SITE

March 2002

Prepared for the:

United States Environmental Protection Agency
Region VIII
999 18th Street, Suite 500
Denver, CO 80202

Prepared by:

Syracuse Research Corporation
Environmental Science Center - Denver
999 18th Street, Suite 1975
Denver, CO 80202

1.0 SITE DESCRIPTION

The Richardson Flats Tailing (RFT) Site is located 1.5 miles northeast of Park City, Utah occupying about 700 acres in a small valley in Summit County, Utah. The RFT site is part of the Park City Mining District where silver-laden ore was mined and milled from the Keetley Ontario Mine as well as other mining operations. Tailings were deposited into an impoundment covering 160 acres of the 700 acre property just east of Silver Creek. Tailings were deposited to the impoundment from the mill by use of a slurry pipeline from 1975 through 1981. Mining and milling operations ended in 1982.

2.0 LAND USE

The site is located in a rural area whose topography is characterized by a broad valley with undeveloped rangeland. Silver Creek is located within a few hundred feet from the main tailings impoundment. Typical land use is limited to recreational purposes. It is not envisioned, for the purposes of the human health risk assessment, that this property will be developed for residential purposes. However, it is envisioned that modifications to the site as a recreational park could be implemented.

There are a wide variety of different recreational activities which people may engage in at this site, and hence there are a wide variety of different recreational exposure scenarios which might warrant evaluation. Two separate scenarios were considered to serve as the representative population evaluated:

- low intensity uses such as, hiking, biking, and picnicking
- high intensity uses such as, horseback riding, ATV use, dirt-biking, soccer and baseball

The risk assessment will be based on the assumption that no further remedial or construction activities will occur at the site. That is, the activities listed will be assumed to occur on current contaminated site conditions, rather than on baseball and/or soccer fields created using clean fill material, sod and turf.

3.0 EXPOSURE SCENARIOS

3.1 Recreational Visitor – Low Intensity Activities

This scenario envisions an open-space visitor who engages in lower intensity activities at the site, including; hiking, biking, and picnicking. Potential pathways of exposure include:

- ingestion of tailings/soil
- inhalation of particulates

It is assumed that this low intensity recreational visitor may occasionally be exposed to surface water and sediments at or near the site. These pathways are further discussed in Section 3.3.

3.2 Recreational Visitor – High Intensity Activities

This scenario envisions a recreational site visitor who engages in higher intensity activities at the site, including; horseback riding, ATV use, dirt biking, soccer, baseball. Potential pathways of exposure include:

- ingestion of tailings/soil
- inhalation of particulates

3.3 Exposure to Surface Water & Sediment

Exposure of low intensity recreational visitors to surface water and sediment at the site are being evaluated separately at the request of the site RPM. Two locations where exposure might occur to surface water and sediment include: onsite ponded water areas and Silver Creek. Each of these locations will be evaluated separately for the recreational user who may frequent these water sources on occasion. Potential pathways of exposure include:

- ingestion of sediment
- dermal contact with water
- ingestion of surface water

Recreational visitors can get contaminated soil/tailings/sediments on their skin while engaging in recreational activities. Dermal contact with contaminated soil is of potential health concern mainly because some chemicals can be absorbed across the skin into the blood, but dermal irritation (e.g., due to contact with acidic tailings) may also occur. Even though information is limited on the rate and extent of dermal absorption of metals in soil across the skin, most scientists consider that this pathway is likely to be minor in comparison to the amount of exposure that occurs by soil and dust ingestion. This view is based on the following concepts: 1) most people do not have extensive and frequent direct contact with soil, 2) most metals tend to bind to soils, reducing the likelihood that they would dissociate from the soil and cross the skin, and 3) ionic species such as metals have a relatively low tendency to cross the skin even when contact does occur. These presumptions are supported by screening level calculations which indicate that dermal exposure of most metals is likely to be no larger (and probably much lower) than absorption due to soil ingestion. Based on these considerations, along with a lack of data to allow reliable estimation of dermal uptake of metals from soil, it is generally recommended that dermal exposure to metals in soils not be evaluated quantitatively. Therefore, this pathway will not be evaluated quantitatively in the risk assessment.

4.0 EXPOSURE ASSUMPTIONS FOR NON-LEAD COPCS

The following pages provide draft exposure parameters for each of the populations and each of the scenarios outlined above. Whenever possible the draft value is based on standard default EPA guidance. Some values, however, remain based on professional judgment or reflect those used at similar sites. All of these parameters should be reviewed and subjected to a site-specific reality check. Input and suggestions from all concerned parties is requested.

For every exposure pathway of potential concern, it is expected that there will be differences between different individuals in the level of exposure at a specific location due to differences in intake rates, body weights, exposure frequencies, and exposure durations. Thus, there is normally a wide range of average daily intakes between different members of an exposed population. Because of this, all daily intake calculations must specify what part of the range of doses is being estimated. Typically, attention is focused on intakes that are "average" or are otherwise near the central portion of the range, and on intakes that are near the upper end of the range (e.g., the 95th percentile). These two exposure estimates are referred to as Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME), respectively.

The USEPA has collected a wide variety of data and has performed a number of studies to help establish default values for most residential and worker exposure parameters. The chief sources of these standard default values are the following documents:

1. Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A). EPA 1989.

2. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". EPA 1991.

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The following sections list the exposure parameters recommended for evaluation of low and high intensity recreational visitors by inhalation, ingestion of and dermal contact with surface water, and incidental ingestion of soil or sediment, along with the resulting HIF terms for CTE and RME exposure. Due to a lack of site specific data, recreational visitors, both low and high intensity, were assumed to visit the site either 50 (CTE) or 100 (RME) days per year based on a study conducted in Jefferson County, Colorado, which evaluated the frequency of open space visits over a 12-month period, as reported by 779 respondents (EPA, 2001).

4.1 Recreational Visitor – Low Intensity Activities

Receptor Population: combined child (1 - 6 yrs) and adult (7+ yrs)
Exposure Frequency: 50 days/year (CTE), 100 days/year (RME), (EPA, 2001)
Health Endpoint: cancer (chronic exposure), non-cancer
Exposure Pathways: soil/tailing ingestion, inhalation of particulates

4.1.1 Soil/Tailings Ingestion

Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (EPA 1989, 1991, 1993), as follows:

$$TWA\text{-}DI_s = C_s\left(\frac{IR_c}{BW_c}\bullet\frac{EF_c\bullet ED_c}{(AT_c+AT_a)}+\frac{IR_a}{BW_a}\bullet\frac{EF_a\bullet ED_a}{(AT_c+AT_a)}\right)$$

where:

$TWA\text{-}DI_s$ = Time-weighted Daily Intake from ingestion of soil/tailings (mg/kg-d)
C_s = Concentration of chemical in soil/tailings (mg/kg)
IR = Intake rate (kg/day) when a child (IR_c) or an adult (IR_a)
BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)

Default values and assumptions recommended by EPA (1989, 1991a, 1993a) for evaluation of exposure to soil/tailings are listed below. There are no data on ingestion rates of tailings by children or adults while engaged in recreational activities at this site. Therefore, based on professional judgment, ingestion rates of soil/tailings of 50 mg/day and 100 mg/day are assumed for adult and child RME low intensity visitors respectively. For CTE visitors, these values were assumed to be half of that attributable to the RME exposure (25 mg/day and 50 mg/day).

Exposure Parameter	CTE		RME	
	Child	Adult	Child	Adult
IR (kg/day)	5E-05	2.5E-05	1E-04	5E-05
BW (kg)	15	70	15	70
EF (days/yr)	50	50	100	100
ED (years)	2	7	6	24
AT (noncancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on the exposure parameters above, the HIFs for exposure of children and adults to soil/tailings are as follows:

Residential Exposure to Soil/Tailings	HIF_{sd} (kg/kg-d)	
	CTE	RME
TWA-chronic (non-cancer)	1.4E-07	5.2E-07
TWA-lifetime (cancer)	1.8E-08	2.2E-07

4.1.2 Inhalation of Particulates

The basic equation recommended by EPA (1989) for evaluation of risks due to inhalation exposure to a chemical in air is:

$$TWA\text{-}DI_p = C_p\left(\frac{IR_c}{BW_c}\bullet\frac{ET_c\bullet EF_c\bullet ED_c}{(AT_c+AT_a)}+\frac{IR_a}{BW_a}\bullet\frac{ET_a\bullet EF_a\bullet ED_a}{(AT_c+AT_a)}\right)$$

where:

$TWA\text{-}DI_p$ = Time-weighted Daily Intake from inhalation of particulates
C_p = Concentration of chemical in air (mg/m^3)
IR = Breathing rate of air (m^3/hour) when a child (IR_c) or an adult (IR_a)
ET = Exposure time (hours/day) when a child (ET_c) or an adult (ET_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)
BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
AT = Averaging time (days)

Default values and assumptions recommended by EPA (1989, 1991, 1993) for evaluation of exposure to particulates in air are listed below. Inhalation rates of 1.6 m^3/hr for children and 2.4 m^3/hr for adults are based on the average of medium and heavy activity inhalation rates for these age groups. This information is from the 1997 Exposure Factors Handbook and was used as inputs in the Rocky Flats Task 3 Report (EPA, 2001). The Exposure Time was based on the 1995 Boulder County open space survey (EPA, 2001) of time spent on site (19% < 1 hour, 71% 1-3 hours, 9% 4-6 hours, and 1% >7 hours). Values of 1.5 and 2.5 hours/day were selected for the CTE and RME exposures, respectively. Although this information pertains to a different site, the values are judged to be applicable at Richardson Flats. The Particulate Emissions Factor (PEF) is the default value established by EPA.

Exposure Parameter	CTE		RME	
	Child	Adult	Child	Adult
IR (m^3/hr)	1.6	2.4	1.6	2.4
BW (kg)	15	70	15	70
PEF (kg/m^3)	7.6E-10	7.6E-10	7.6E-10	7.6E-10
ET (hr/day)	1.5	1.5	2.5	2.5
EF (days/yr)	50	50	100	100
ED (years)	2	7	6	24
AT (noncancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on the exposure parameters above, the HIFs for exposure of children and adults to particulates are as follows:

Exposure to Particulates	HIF_p (m^3/kg-d)	
	CTE	RME
TWA-chronic (non-cancer)	1.0E-02	3.3E-02
TWA-lifetime (cancer)	1.3E-03	1.4E-02

4.2 Recreational Visitor – High Intensity Activities

Receptor Population: Adult (7+ yrs)
Exposure Frequency: 50 days/year (CTE), 100 days/year (RME), (EPA, 2001)
Health Endpoint: cancer (chronic exposure), non-cancer
Exposure Pathways: soil/tailing ingestion, inhalation of particulates

4.2.1 Soil/Tailings Ingestion

The basic equation used to assess risks from incidental ingestion of tailings or contaminated soil by recreational visitors is as follows:

$$DI_t = C_t\left(\frac{IR_t}{BW}\right)\left(\frac{EF_t \bullet ED}{AT}\right)$$

where:

DI_t	=	Daily intake of chemical from ingestion of soil/tailings (mg/kg-d)
C_t	=	Concentration of chemical in tailings (mg/kg)
IR_t	=	Intake rate of tailings (kg/day)
BW	=	Body weight of the exposed person (kg)
EF_t	=	Exposure frequency to tailings (days/year)
ED	=	Exposure duration (years)
AT	=	Averaging time (days)

There are no data on ingestion rates of tailings by adults while engaged in high intensity recreational activities at this site. Therefore, based on professional judgment, ingestion rates of soil/tailings of 50 mg/day and 100 mg/day are assumed for CTE and RME exposure, respectively. Assuming an approximate site visit of 2 hours, these values (25 mg/hr CTE, 50 mg/hr RME) are approximately equal to 8 times the levels of soil that an adult resident is expected to ingest on an hourly basis. The RME default ingestion value for a residential adult is 100 mg/day for an adult, or 6.3 mg/hr based on a 16 hour day. Since it is expected that a recreational visitor will consume more soil than a typical resident on an hourly basis, these values are judged appropriate for use at this site. Additionally, since it is expected that higher intensity activities will lead to increased ingestion of soil/tailings, these values are 2-fold higher than those selected for use under the low-intensity activity scenario.

The exposure parameters are summarized below:

Parameter	CTE	RME
IR (kg/day)	5E-05	1E-04
BW (kg)	70	70
EF (days/yr)	50	100
ED (years)	7	24
AT (noncancer effects) (days)	6·365	24·365
AT (cancer effects) (days)	70·365	70·365

Based on these exposure parameters, the HIF values for exposure of high intensity recreational visitors to tailings and contaminated soil are as follows:

Recreational Exposure to soil/tailings	HIF (kg/kg-d)	
	CTE	RME
Chronic (non-cancer)	9.8E-08	3.9E-07
Lifetime (cancer)	9.8E-09	1.3E-07

4.2.2 Inhalation of Particulates

The basic equation recommended by EPA (1989) for evaluation of risks due to inhalation exposure to a chemical in air is:

$$DI_{air} = C_a \cdot (BR/BW) \cdot (ET \cdot EF \cdot ED/AT)$$

where:

DI_{air} = Risk from inhalation exposure to a chemical in air
C_{air} = Concentration of chemical in air (mg/m^3)
BR = Breathing rate of air (m^3/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/yr)
ED = Exposure duration (yrs)
BW = Body weight (kg)
AT = Averaging time (days)
TF_{inhal} = Toxicity factor for the inhalation pathway

Default values and assumptions recommended by EPA (1989, 1991, 1993) for evaluation of exposure to particulates in air are listed below. An inhalation rate of 2.4 m^3/hr for

adults was based on the average of medium and heavy activity inhalation rates for this age group. This information is from the 1997 Exposure Factors Handbook and was used as inputs in the Rocky Flats Task 3 Report (EPA, 2001). The Exposure Time was based on the 1995 Boulder County open space survey (EPA, 2001) of time spent on site (19% < 1 hour, 71% 1-3 hours, 9% 4-6 hours, and 1% >7 hours). Values of 1.5 and 2.5 hours/day were selected for the CTE and RME exposures, respectively. Although this information pertains to a different site, the values are judged to be applicable at Richardson Flats. The PEF value is based on a value established for all-terrain vehicle (ATV) usage at an old mine tailings site (Arizona Department of Health Services) and is thought to be appropriate for use at this site.

Exposure Parameter	CTE	RME
BR (m^3/hr)	2.4	2.4
BW (kg)	70	70
PEF (kg/m^3)	4.6E-09	4.6E-09
ET (hours/day)	1.5	2.5
EF (days/yr)	50	100
ED (years)	7	24
AT (noncancer effects) (days)	6·365	24·365
AT (cancer effects) (days)	70·365	70·365

Based on the exposure parameters above, the HIFs for exposure to particulates are as follows:

Exposure to Particulates	HIF_p (m^3/kg-d)	
	CTE	RME
TWA-chronic (non-cancer)	7.0E-03	2.3E-02
TWA-lifetime (cancer)	7.0E-04	8.1E-03

4.3 Exposure to Surface Water & Sediment

Receptor Population: combined child (1 - 6 yrs) and adult (7+ yrs)
Exposure Frequency: 5 days/year (CTE), 10 days/year (RME): this assumes that the low intensity visitor is exposed to these media during 1 out of every 10 standard site visits
Health Endpoint: cancer (chronic exposure), non-cancer

Exposure Pathways: ingestion of sediments, dermal contact with surface water, ingestion of surface water

4.3.1 Ingestion of Sediments

The basic equation used to assess risks from incidental ingestion of sediments by recreational visitors while visiting water areas is as follows. Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (EPA 1989, 1991, 1993):

$$TWA\text{-}DI_s = C_s\left(\frac{IR_c}{BW_c}\bullet\frac{EF_c\bullet ED_c}{(AT_c+AT_a)}+\frac{IR_a}{BW_a}\bullet\frac{EF_a\bullet ED_a}{(AT_c+AT_a)}\right)$$

where:

$TWA\text{-}DI_s$ = Time-weighted Daily Intake from ingestion of sediment (mg/kg-d)
C_s = Concentration of chemical in sediment (mg/kg)
IR = Intake rate (kg/day) when a child (IR_c) or an adult (IR_a)
BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)

There are no data on ingestion rates of sediments by visitors while engaged in recreational activities along the river or in ponded water areas at the site. Therefore, in the absence of data, ingestion rates of soil/tailings of 25 mg/day and 50 mg/day are assumed for adult and child RME visitors respectively. For CTE visitors, these values were assumed to be half of that attributable to the RME exposure (12.5 mg/day and 25 mg/day). This is equivalent to ½ of the quantity consumed by the low intensity recreational visitor from soil/tailings ingestion. The exposure parameters are summarized below:

Exposure Parameter	CTE		RME	
	Child	Adult	Child	Adult
IR (kg/day)	2.5E-05	1.3E-05	5E-05	2.5E-05
BW (kg)	15	70	15	70
EF (days/yr)	5	5	10	10
ED (years)	2	7	6	24
AT (noncancer effects) (days)	2·365	7·365	6·365	24·365

AT (cancer effects) (days)	--	70·365	--	70·365

Based on these exposure parameters, the HIF values for exposure of visitors to sediments are as follows:

Recreational Exposure to Bankside tailings	HIF (kg/kg-d)	
	Average	RME
Chronic (non-cancer)	7.0E-09	2.6E-08
Lifetime (cancer)	9.0E-10	1.1E-08

4.3.2 Dermal Contact with Surface Water

The basic equation recommended by EPA (1989) for evaluation of dermal exposure to a chemical dissolved in water is as follows. Both chronic and lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (EPA 1989, 1991, 1993):

$$AD_{sw} = C_{sw}\left(\frac{SA_c \bullet PC \bullet ET_c \bullet 1E-03}{BW_c} \bullet \frac{EF_c \bullet ED_c}{(AT_c + AT_a)} + \frac{SA_a \bullet PC \bullet ET_a \bullet 1E-03}{BW_a} \bullet \frac{EF_a \bullet ED_a}{(AT_c + AT_a)}\right)$$

where:

AD_{sw} = Absorbed dose from dermal contact with surface water (mg/kg-d)
C_{sw} = Concentration of chemical in surface water (mg/L)
SA = Surface area exposed (cm^2) for child (SA_c) or adult (SA_a)
PC = Chemical-specific permeability constant (cm/hr)
ET = Exposure time (hr/day) for child (ET_c) or adult (ET_a)
1E-03 = Conversion factor (L/cm^3)
EF = Exposure frequency (days/yr) child (EF_c) or adult (EF_a)
ED = Exposure duration (yrs) for child (ED_c) or adult (ED_a)
BW = Body weight (kg) child (BW_c) or adult (BW_a)
AT = Averaging time (days) for child (AT_c) or adult (AT_a)

It is assumed that dermal exposure of a recreation visitor to water occurs mainly while wading near the river edge or ponded areas, and that dermal contact is mainly restricted

to the lower extremities (upper and lower legs and feet) as well as the hands. The surface area for these body parts in children and adults is the 50th percentile for hands, arms, and lower legs (EPA, 1997) (SAF, 2000). No site-specific data on recreation frequency or duration of wading activities per trip are available, so values of 5 (CTE) to 10 (RME) days/year, and 0.5 (CTE) to 1.5 (RME) hours/day are assumed. The exposure time is based on the FE Warren site (SAF, 2000), where estimated time spent in surface waters were evaluated. The value of PC is chemical specific, and few measured values are available for metals. Therefore, the EPA (1992b) suggests using a PC value of 1E-03 cm/hr as a conservative estimate. Other exposure parameters are the same as described above. These exposure parameters are summarized below.

Exposure Parameter	CTE		RME	
	Child	Adult	Child	Adult
SA (cm^2)	3,800	5,000	3,800	5,000
PC (cm/hr)	1E-03	1E-03	1E-03	1E-03
BW (kg)	15	70	15	70
ET (hr/day)	0.5	0.5	1.5	1.5
EF (days/yr)	5	5	10	10
ED (years)	2	7	6	24
AT (noncancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on these exposure parameters, the HIF values for dermal exposure of low intensity recreational visitors to surface water are as follows:

Dermal Exposure to Surface Water	HIF_{rw} (L/kg-d)	
	CTE	RME
Chronic (non-cancer)	7.7E-07	4.4E-06
Lifetime (cancer)	9.8E-08	1.9E-06

4.3.3 Ingestion of Surface Water

The basic equation for evaluation of exposure from ingestion of surface water while participating in water-based recreational activities is as follows. Both chronic and

lifetime average intake rates are time-weighted to account for the possibility that an adult may begin exposure as a child (EPA 1989, 1991, 1993):

$$TWA\text{-}DI_w = C_w\left(\frac{IR_c}{BW_c}\bullet\frac{ET_c\bullet EF_c\bullet ED_c}{(AT_c+AT_a)}+\frac{IR_a}{BW_a}\bullet\frac{ET_a\bullet EF_a\bullet ED_a}{(AT_c+AT_a)}\right)$$

where:

$TWA\text{-}DI_s$ = Time-weighted Daily Intake from ingestion of water (mg/kg-d)
C_s = Concentration of chemical in surface water (mg/L)
IR = Intake rate (L/day) when a child (IR_c) or an adult (IR_a)
BW = Body weight (kg) when a child (BW_c) or an adult (BW_a)
ET = Exposure time (hours/day) when a child (ET_c) or an adult (ET_a)
EF = Exposure frequency (days/yr) when a child (EF_c) or an adult (EF_a)
ED = Exposure duration (years) when a child (ED_c) or an adult (ED_a)
AT = Averaging time (days) while a child (AT_c) or an adult (AT_a)

The rate of water ingestion by recreational visitors was based on values applied in the FE Warren Site Risk Assessment (SAF, 2000). An incidental water ingestion rate of 30 mL/hour is the basis for the 10 mL/day value proposed in the Draft Water Quality Criteria Methodology Revisions (SAF, 2000) and will be used as the RME at this site. The EPA (1989a) recommends a default surface water ingestion rate of 50 mL/hr while swimming. However, recognizing that splashing or hand-to face contact while wading might result in only a very small amount of water in or near the mouth, it is thought that this value is too high under this scenario. Based on this reasoning, a CTE value of 5 mL/hour was assumed. Exposure times are the same as those presented for dermal exposure. These exposure parameters are summarized below:

Exposure Parameter	CTE		RME	
	Child	Adult	Child	Adult
IR (mL/hr)	5	5	30	30
BW (kg)	15	70	15	70
ET (hr/day)	0.5	0.5	1.5	1.5
EF (days/yr)	5	5	10	10
ED (years)	2	7	6	24
AT (noncancer effects) (days)	2·365	7·365	6·365	24·365
AT (cancer effects) (days)	--	70·365	--	70·365

Based on these exposure parameters, the HIF values for ingestion of river water by recreational visitors are as follows:

Recreational Exposure to Surface Water	HIF_{rw} (L/kg-d)	
	Average	RME
Chronic (non-cancer)	8.9E-07	3.1E-05
Lifetime (cancer)	1.1E-07	1.3E-05

5.0 EXPOSURE ASSUMPTIONS FOR LEAD

The biokinetic slope factor approach described by Bowers et al. has been identified by EPA's Technical Workgroup for Lead as a reasonable interim methodology for assessing risks to adults from exposure to lead and for establishing risk-based concentration goals that will protect older children and adults from lead. For this reason, this method was used for estimating soil lead and tailings lead levels that could be of concern to older children and adult visitor engaging in either low-intensity or high-intensity activities at this site. When adults are exposed, the sub-population of chief concern is pregnant women and women of child-bearing age, since the blood lead level of a fetus is nearly equal to the blood lead level of the mother (Goyer 1990). Therefore, the population of concern was shifted to a slightly older (child-bearing age), female visitor.

The Bowers model predicts the blood lead level in an adult exposed to lead in a specified occupational setting by summing the "baseline" blood lead level (PbB_0) (that which would occur in the absence of any above-average site-related exposures) with the increment in blood lead that is expected as a result of increased exposure due to contact with a lead-contaminated site medium. The latter is estimated by multiplying the absorbed dose of lead from site-related exposure by a "biokinetic slope factor" (BKSF). Thus, the basic equation is:

$$PbB = PbB_0 + (PbS \cdot BKSF \cdot IR_s \cdot AF_s \cdot EF_s)/AT$$

where:

PbB = Central estimate of blood lead concentrations (ug/dL) in adults (i.e., women of child-bearing age) that have site exposures to soil lead at concentration, PbS.

PbB_0 = Typical blood lead concentration (ug/dL) in adults (i.e., women of child-bearing age) in the absence of exposures to the site that is being assessed.

BKSF = Biokinetic slope factor relating (quasi-steady state) increase in typical adult blood lead concentration to average daily lead uptake (ug/dL blood lead increase per ug/day lead uptake)

PbS = Soil lead concentration (ug/g) (appropriate average concentration for individual)

IR_s = Intake rate of soil, including both outdoor soil and indoor soil-derived dust (g/day)

AF_s = Absolute gastrointestinal absorption fraction for ingested lead in soil and lead in dust derived from soil (dimensionless). The value of AF_s is given by:

$$AF_s = AF(food) * RBA(soil)$$

EF_s = Exposure frequency for contact with assessed soils and/or dust derived in part from these soils (days of exposure during the averaging period)

AT = Averaging time; the total period during which soil contact may occur; 365 days/year for continuing long term exposures.

Once the geometric mean blood lead value is calculated, the full distribution of likely blood lead values in the population of exposed people can then be estimated by assuming the distribution is lognormal with some specified geometric standard deviation (GSD). Specifically, the 95th percentile of the predicted distribution is given by the following equation (Aitchison and Brown 1957):

$$95th = GM \cdot GSD^{1.645}$$

Input values selected for each of these parameters are summarized below:

Parameter	Low Intensity		High Intensity	
	Value	Source	Value	Source
PbB_0 (ug/dL)	1.4	EPA (1996) and Based on mean of females age 12-19 and age 20-49 years (Brody et al. 1994)	1.4	EPA (1996) and Based on mean of females age 12-19 and age 20-49 years (Brody et al. 1994)
PbS (ppm)	varied	Table 5-1	varied	Table 5-1
BKSF (ug/dL per ug/day)	0.4	EPA (1996)	0.4	EPA (1996)
IR (g/day exposed)	0.025	Based on intake rate of 25 mg/day. Multiplied by a factor of 1E-03 g/mg.	0.05	Based on intake rate of 50 mg/day. Multiplied by a factor of 1E-03 g/mg.
EF_s (days exposed/yr)	50	Based on exposure assumptions discussed for Non-Lead COPCs	50	Based on exposure assumptions discussed for Non-Lead COPCs
AT (days)	365	EPA (1996)	365	EPA (1996)
AF_o (unitless)	0.12	Based on an absorption factor for soluble lead of 0.20 (USEPA 1996) and a relative bioavailability of 0.6	0.12	Based on an absorption factor for soluble lead of 0.20 (USEPA 1996) and a relative bioavailability of 0.6
GSD	1.8	Based on homogenous population (EPA 1996)	1.8	Based on homogenous population (EPA 1996)

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APPENDIX C

SCREENING LEVEL EVALUATION OF RELATIVE RISK FROM DERMAL CONTACT WITH SOIL

1.0 DERMAL EXPOSURE VIA SOIL

The basic equation recommended for estimation of dermal dose from contact with soils is as follows (EPA 1989, 1992):

$$AD_{soil} = C_s \cdot SA \cdot AF \cdot ABS \cdot EF \cdot ED/(BW \cdot AT)$$

where:

C_s	=	concentration of chemical in soil (mg/kg)
SA	=	surface area in contact with soil (cm^2)
AF	=	soil adherence factor (kg/cm^2)
ABS	=	absorption fraction (unitless)

At the present time, data are very limited on the value of the ABS term, and the EPA (1992) has concluded that there are only three chemicals for which sufficient data exist to estimate credible ABS values, as shown below:

Chemical	ABS
Dioxins	0.1-3%
PCBs	0.6-6%
Cadmium	0.1-1%

It is important to realize that even these values are rather uncertain, due to a variety of differences between the exposure conditions used in laboratory studies of dermal absorption and exposure conditions that are likely to occur at Superfund sites. For example, most laboratory studies use much higher soil loadings on the skin (e.g., 5-50 mg/cm^2) than are expected to occur at sites (0.2-1 mg/cm^2). Also, most studies investigate the amount absorbed after a relatively lengthy contact period (16-96 hours), while it is expected that most people would wash off soil on the skin more promptly than this. Because of these difficulties in extrapolation from experimental measurements to "real-life" conditions, the values above are only considered approximate, and are more likely to be high than low. With respect to estimating ABS values for other chemicals (those for which there are no reliable experimental measurements), the EPA

concludes that current methods are not sufficiently developed to calculate values from available data such as physical-chemical properties.

If values of ABS were available for the site COPCs, the relative magnitude of the dermal dose to the oral dose would be calculated as follows:

$$\frac{AD_d}{AD_o} = \frac{SA \cdot AF \cdot ABS \cdot EF_d}{IR \cdot AF_o \cdot EF_o}$$

where:

SA	=	surface area in contact with soil (cm^2)
AF	=	soil adherence factor (kg/cm^2)
ABS	=	absorption fraction (unitless)
IR_w	=	Ingestion rate of water (cm^3/day)
AF_o	=	Oral absorption fraction
EF_d	=	Dermal exposure frequency (days/yr)
EF_o	=	Dermal exposure frequency (days/yr)

Assuming that 10% of the body area (2,000 cm^2) is covered with soil (1 mg/cm^2 = 1E-06 kg/cm^2) for 50 days/yr, the ratio of the predicted dermal absorbed dose to the oral absorbed dose is given by:

$$\frac{AD_d}{AD_o} = 2.86 \frac{ABS}{AF_o}$$

If, by extrapolation from cadmium, the ABS is assumed to be 0.1-1% for site COPCs, then the ratio of dermal dose from soil to oral dose from soil are as follows:

Chemical	ABS (assumed)	AFo	Dose Ratio (dermal/oral)
Non-Lead COPCs	0.001-0.01	1	0.3-3%
Lead	0.001-0.01	0.1	3-28%

Because the value of ABS is not available for the site COPCs, these values should not be considered to be reliable. However, this calculation does support the conclusion that dermal absorption of metals from dermal contact with soil is likely to be relatively minor compared to the oral pathway, and omission of this pathway is not likely to lead to a substantial underestimate of exposure or risk.

4.0 REFERENCES

EPA. 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual Part A. Interim Final. Office of Solid Waste and Emergency Response (OSWER), Washington, DC. OSWER Directive 9285.701A.

EPA. 1992. Dermal Exposure Assessment: Principles and Applications. Interim Report. Office of Research and Development, Washington, DC. EPA/600/8-91/011B.

APPENDIX D

DETAILED RISK CALCULATIONS

Exposure Point Concentrations

Location	Medium	Chemical	Detect Frequency	Max Value	Max Hit	Min Value	GM	AM	Stdev	UCL95 Norm	UCL95 LogNorm	EPC
On-site	Sediment	Arsenic	12/12	3.1E+02	3.1E+02	1.0E+02	1.5E+02	1.6E+02	6.0E+01	1.9E+02	2.0E+02	2.0E+02
On-site	Sediment	Lead	12/12	6.5E+03	6.5E+03	1.9E+03	3.2E+03	3.5E+03	1.6E+03	4.3E+03	4.4E+03	3.5E+03

Location	Medium	Chemical	Detect Frequency	Max Value	Max Hit	Min Value	GM	AM	Stdev	UCL95 Norm	UCL95 LogNorm	EPC
On-site	Surface Water	Arsenic	81/246	7.5E-01	7.5E-01	2.5E-03	4.7E-03	8.8E-03	4.8E-02	1.4E-02	6.7E-03	1.4E-02
On-site	Surface Water	Lead	243/427	2.6E+01	2.6E+01	1.5E-03	1.3E-02	1.3E-01	1.3E+00	2.4E-01	7.0E-02	1.3E-01

Location	Medium	Chemical	Detect Frequency	Max Value	Max Hit	Min Value	GM	AM	Stdev	UCL95 Norm	UCL95 LogNorm	EPC
On-site	Soil & Tailings	Arsenic	59/64	2.4E+02	2.4E+02	2.5E+00	1.7E+01	4.1E+01	6.4E+01	5.4E+01	5.5E+01	5.5E+01
On-site	Soil & Tailings	Lead	62/62	5.9E+03	5.9E+03	1.4E+01	1.2E+02	6.6E+02	1.4E+03	9.5E+02	1.3E+03	6.6E+02

Estimated Concentrations of Arsenic in Air

LOW INTENSITY USER

Soil EPC mg/kg	PEF kg/m3	Estimated Air Conc mg/m3
5.5E+01	7.60E-10	4.21E-08

HIGH INTENSITY USER

Soil EPC mg/kg	PEF kg/m3	Estimated Air Conc mg/m3
5.5E+01	4.60E-09	2.55E-07

Intake Parameters

			Average	RME
Low Intensity Recreational User	Soil/Tailings Ingestion	Non-Cancer	1.39523E-07	5.21853E-07
		Cancer	1.79387E-08	2.23651E-07
	Soil/Tailings Inhalation	Non-Cancer	0.010350076	0.033398565
		Cancer	0.001330724	0.014313671
	Ingestion of Surface Water	Non-Cancer	8.87874E-07	3.05284E-05
		Cancer	1.14155E-07	1.30836E-05
High Intensity Recreational User	Soil/Tailings Ingestion	Non-Cancer	9.78474E-08	3.91389E-07
		Cancer	9.78474E-09	1.34191E-07
	Soil/Tailings Inhalation	Non-Cancer	0.00704501	0.023483366
		Cancer	0.000704501	0.00805144
	Dermal Contact w/ Surface Water	Non-Cancer	7.66109E-07	4.43053E-06
		Cancer	9.84997E-08	1.8988E-06
	Ingestion of Sediment	Non-Cancer	6.97615E-09	2.60926E-08
		Cancer	8.96934E-10	1.11826E-08

Toxicity Values

Soil & Tailings

Non-Cancer	oRfD	Unit	Source	Effect
Arsenic	3.0E-04	mg/kg-d	IRIS	hyperpigmentation

Cancer	oSF	Unit	Source
Arsenic	1.5E+00	$(mg/kg\text{-}d)^{-1}$	IRIS

Bioavailability factors

	Ingestion	Inhalation
Arsenic	0.80	0.80

Surface Water

Non-Cancer	oRfD	Unit	Source	Effect
Arsenic	3.0E-04	mg/kg-d	IRIS	hyperpigmentation

Cancer	oSF	Unit	Source
Arsenic	1.5E+00	$(mg/kg\text{-}d)^{-1}$	IRIS

Bioavailability factors

Arsenic	1.00

Sediment

Non-Cancer	oRfD	Unit	Source	Effect
Arsenic	3.0E-04	mg/kg-d	IRIS	hyperpigmentation

Cancer	oSF	Unit	Source
Arsenic	1.5E+00	$(mg/kg\text{-}d)^{-1}$	IRIS

Bioavailability factors

Arsenic	0.80

Air

Non-Cancer	RfC*	Unit	Source	Effect
Arsenic	3.0E-04	mg/kg-d	* Oral RfD is used b/c no inhalation value available	

Cancer	iSF	Unit	Source
Arsenic	1.5E+01	$(mg/kg\text{-}d)^{-1}$	IRIS

Bioavailability factors

Arsenic	0.80

RISK CALCULATIONS FOR CHEMICALS IN SEDIMENT

INGESTION OF SEDIMENT

Part A: Noncancer Risks

				Average					RME		
	EPC	HIF	RBA	DI	RfD	HQ	HIF	RBA	DI	RfD	HQ
Analyte	**mg/kg**	**kg/kg-d**	**--**	**mg/kg-d**		**--**	**kg/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	1.98E+02	6.98E-09	0.80	1.1E-06	3.0E-04	3.7E-03	2.61E-08	0.80	4.1E-06	3.0E-04	1.4E-02
Total						3.7E-03					1.4E-02

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	**mg/kg**	**kg/kg-d**	**--**	**mg/kg-d**		**--**	**kg/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	1.98E+02	8.97E-10	0.80	1.42E-07	1.5E+00	2.7E-07	1.12E-08	0.80	1.77E-06	1.5E+00	3.3E-06
Total						*3E-07*					*3E-06*

RISK CALCULATIONS FOR CHEMICALS IN SURFACE WATER

INGESTION OF SURFACE WATER

Part A: Noncancer Risks

		Average					RME				
	EPC	HIF	RBA	DI	RfD	HQ	HIF	RBA	DI	RfD	HQ
Analyte	mg/L	L/kg-d	--	mg/kg-d		--	L/kg-d	--	mg/kg-d		--
Arsenic	1.38E-02	8.88E-07	1.00	1.2E-08	3.0E-04	4.1E-05	3.05E-05	1.00	4.2E-07	3.0E-04	1.4E-03
Total						4.1E-05					1.4E-03

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	mg/L	L/kg-d	--	mg/kg-d		--	L/kg-d	--	mg/kg-d		--
Arsenic	1.38E-02	1.14E-07	1.00	1.58E-09	1.5E+00	2.4E-09	1.31E-05	1.00	1.81E-07	1.5E+00	2.7E-07
Total						*2E-09*					*3E-07*

DERMAL CONTACT WITH SURFACE WATER

Part A: Noncancer Risks

		Average					RME				
Chemical	EPC	HIF	RBA	DI	RfD	HQ	HIF	RBA	DI	RfD	HQ
Analyte	mg/L	L/kg-d	--	mg/kg-d		--	L/kg-d	--	mg/kg-d		--
Arsenic	1.38E-02	7.66E-07	1.00	1.1E-08	3.0E-04	3.5E-05	4.4E-06	1.00	6.1E-08	3.0E-04	2.0E-04
Total						3.5E-05					2.0E-04

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	mg/L	L/kg-d	--	mg/kg-d		--	L/kg-d	--	mg/kg-d		--
Arsenic	1.38E-02	9.85E-08	1.00	1.36E-09	1.5E+00	2.0E-09	1.90E-06	1.00	2.62E-08	1.5E+00	3.9E-08
Total						*2E-09*					*4E-08*

RISK CALCULATIONS FOR CHEMICALS IN SOIL AND TAILINGS

INGESTION OF SOIL/TAIILING
Low-Intensity User

Part A: Noncancer Risks

		Average					RME				
	EPC	HIF	RBA	DI	RfD	HQ	HIF	RBA	DI	RfD	HQ
Analyte	**mg/kg**	**kg/kg-d**	**--**	**mg/kg-d**		**--**	**kg/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	5.54E+01	1.40E-07	0.80	6.2E-06	3.0E-04	2.1E-02	5.22E-07	0.80	2.3E-05	3.0E-04	7.7E-02
Total						*2.1E-02*					*7.7E-02*

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	**mg/kg**	**kg/kg-d**	**--**	**mg/kg-d**		**--**	**kg/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	5.54E+01	1.79E-08	0.80	7.95E-07	1.5E+00	1.5E-06	2.24E-07	0.80	9.92E-06	1.5E+00	1.9E-05
Total						*1E-06*					*2E-05*

INGESTION OF SOIL/TAIILING
High-Intensity User

Part A: Noncancer Risks

		Average					RME				
	EPC	HIF	RBA	DI	RfD	HQ	HIF	RBA	DI	RfD	HQ
Analyte	**mg/kg**	**kg/kg-d**	**--**	**mg/kg-d**		**--**	**kg/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	5.54E+01	9.78E-08	0.80	4.3E-06	3.0E-04	1.4E-02	3.91E-07	0.80	1.7E-05	3.0E-04	5.8E-02
Total						*1.4E-02*					*5.8E-02*

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	**mg/kg**	**kg/kg-d**	**--**	**mg/kg-d**		**--**	**kg/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	5.54E+01	9.78E-09	0.80	4.34E-07	1.5E+00	8.1E-07	1.34E-07	0.80	5.95E-06	1.5E+00	1.1E-05
Total						*8E-07*					*1E-05*

RISK CALCULATIONS FOR CHEMICALS IN AIR (FROM SOIL AND TAILINGS)

INHALATION OF AIR
Low-Intensity User

Part A: Noncancer Risks

				Average					RME			
	EPC	HIF	RBA	DI	RfC	HQ	HIF	RBA	DI	RfC	HQ
Analyte	**mg/m^3**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	4.21E-08	1.04E-02	0.80	3.5E-10	3.0E-04	1.2E-06	3.34E-02	0.80	1.1E-09	3.0E-04	3.8E-06
Total						*1.2E-06*					*3.8E-06*

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	**mg/m^3**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	4.21E-08	1.33E-03	0.80	4.48E-11	1.5E+01	8.4E-10	1.43E-02	0.80	4.82E-10	1.5E+01	9.0E-09
Total						*8E-10*					*9E-09*

INHALATION OF AIR
High-Intensity User

Part A: Noncancer Risks

				Average					RME			
	EPC	HIF	RBA	DI	RfC	HQ	HIF	RBA	DI	RfC	HQ
Analyte	**mg/m^3**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	2.55E-07	7.05E-03	0.80	1.4E-09	3.0E-04	4.8E-06	2.35E-02	0.80	4.8E-09	3.0E-04	1.6E-05
Total						*4.8E-06*					*1.6E-05*

Part B: Cancer Risks

	EPC	HIF	RBA	DI	SF	Risk	HIF	RBA	DI	SF	Risk
Analyte	**mg/m^3**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**	**m^3/kg-d**	**--**	**mg/kg-d**		**--**
Arsenic	2.55E-07	7.05E-04	0.80	1.44E-10	1.5E+01	2.7E-09	8.05E-03	0.80	1.64E-09	1.5E+01	3.1E-08
Total	4.21E-08					*3E-09*					*3E-08*

Risk Estimate Summary

Part A: Non-Cancer Risks from Arsenic

		Average	RME
Low Intensity	Sediment Ingestion	3.7E-03	1.4E-02
	Surface Water Ingestion	4.1E-05	1.4E-03
	Dermal Contact with Surface Water	3.5E-05	2.0E-04
	Low Intensity User Soil Ingestion	2.1E-02	7.7E-02
	Low Intensity User Air Inhalation	1.2E-06	3.8E-06
High Intensity	High Intensity User Soil Ingestion	1.4E-02	5.8E-02
	High Intensity User Air Inhalation	4.8E-06	9.0E-09
	Total Low Intensity User	*2.4E-02*	*9.3E-02*
	Total High Intensity User	*1.4E-02*	*5.8E-02*

Part B: Cancer Risks from Arsenic

		Average	RME
Low Intensity	Sediment Ingestion	2.7E-07	3.3E-06
	Surface Water Ingestion	2.4E-09	2.7E-07
	Dermal Contact with Surface Water	2.0E-09	3.9E-08
	Low Intensity User Soil Ingestion	1.5E-06	1.9E-05
	Low Intensity User Air Inhalation	8.4E-10	9.0E-09
High Intensity	High Intensity User Soil Ingestion	8.1E-07	1.1E-05
	High Intensity User Air Inhalation	2.7E-09	3.1E-08
	Total Low Intensity User	*1.8E-06*	*2.2E-05*
	Total High Intensity User	*8.2E-07*	*1.1E-05*

APPENDIX E

IEUBK MODEL

IEUBK MODEL INPUT PARAMETERS FOR LEAD

For this site, two simulations were run using the IEUBK model. The first evaluated risks to a hypothetical nearby resident. The second simulation was used to address the risk observed when the hypothetical residential child engaged in recreational activities at the site.

Dietary Lead Intake: Values used for this site are equal to 70% of the EPA default values as follows. Rationale for the use of these values was presented in the Draft Baseline Human Health Risk Assessment for this site (EPA, 2001)

Age (years)	70% Dietary Intake (ug/day)
0-1	3.87
1-2	4.05
2-3	4.54
3-4	4.37
4-5	4.21
5-6	4.44
6-7	4.9

Geometric Standard Deviation (GSD): The GSD recommended as the default for the IEUBK model is 1.6 (USEPA 1994). However, several blood lead studies that have been performed in the Salt Lake City area have yielded GSD estimates of about 1.4 (Griffin et al., 1999b). Therefore, values of both 1.6 and 1.4 were evaluated in this assessment.

Soil Intake: Background soils were collected from areas surrounding the site. Although the samples do not represent "pristine" (not influenced by human activity) environmental levels, they are thought to be adequate to serve as a potential "off-site" residential concentration. Therefore, these background data were compiled and a value of 64 mg/kg of lead in soil, representing the log-normal UCL95 value was utilized for residential exposure. Intake parameters for the residential scenario were kept as IEUBK model defaults and it was assumed that none of the soil intake was attributable to dust.

The second scenario combined the residential parameters with those for occasional recreational visits. These visitor parameters were based on the average child who is thought to engage in recreational activities 50 days/year and consume 100 mg of soil during each recreational event. Because recreational activities are not thought to occur 365 days/year, a time-weighted approach was used to derive values for input into the IEUBK model. Therefore, if the child visited a site 50 days/year they were exposed to their soil intake at the site on those days. For the remaining

315 days/year the child was assumed to be exposed at home at the concentration specified above. The concentration utilized for recreational exposure was the log-normal UCL95 of the surficial on-site soil and tailings, which was determined to be 1,331 mg/kg. The following table summarizes both intake and concentration parameters for soil/tailings. The weighted average value shows the number input into the IEUBK model for the combined residential/recreational exposure scenario.

Age	Scenario	Days/Year	Intake (mg/day)	Concentration (mg/kg)
0-1	Residential	315	85	64
	Recreational	50	100	1331
	Weighted Average	**365**	**87**	**263**
1-2	Residential	315	135	64
	Recreational	50	100	1331
	Weighted Average	**365**	**130**	**197**
2-3	Residential	315	135	64
	Recreational	50	100	1331
	Weighted Average	**365**	**130**	**197**
3-4	Residential	315	135	64
	Recreational	50	100	1331
	Weighted Average	**365**	**130**	**197**
4-5	Residential	315	100	64
	Recreational	50	100	1331
	Weighted Average	**365**	**100**	**238**
5-6	Residential	315	90	64
	Recreational	50	100	1331
	Weighted Average	**365**	**91**	**254**
6-7	Residential	315	85	64
	Recreational	50	100	1331
	Weighted Average	**365**	**87**	**263**

Water Lead Concentrations: For this analysis, lead concentrations in water and intake assumptions for each scenario were calculated according to the approach used above for soil/tailings. Residential water concentrations and intakes were set equal to the IEUBK default values. Because the intake rates (5 mL/event) and the site-specific lead concentrations (0.07

ug/L) are so low, the calculated weighted average was the same for the combined residential/recreational scenario as for the residential alone. Therefore, these values were the same in both model simulations.

Water Intake: At this site water intake was assumed to be based on recreational exposure to site surface waters. Based on an RME intake of 30 mL/hr for1.5 hr/day over 10 days/yr, an equivalent of 1.23 mL/day (0.0012 L/day) on a yearly basis was calculated. This intake was used for all age groups.

Air Inhalation: Lead values for air were kept at the IEUBK default value of 0.1 ug/m^3. This is based on the observation that the maximum lead concentrations in soil/tailing (5,875 mg/kg) would result in a predicted air concentration of 0.03 ug/m^3 using a PEF of 4.6E-9 kg/m3 based on ATV (high intensity) activities. Because this number was lower than the default value, the default was retained in the IEUBK model.

Bioavailability: The default value of 0.60 was used for soil/tailings and sediment. This value corresponds to an absolute bioavailability of 0.30 as required for use in the IEUBK model.

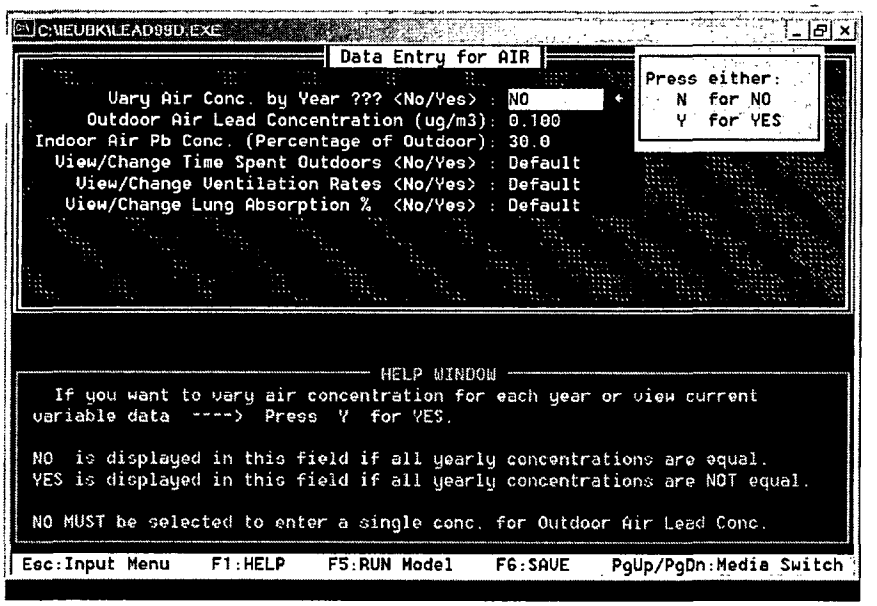
Age Range: Geometric mean blood lead values were calculated for children aged 0 – 84 months.

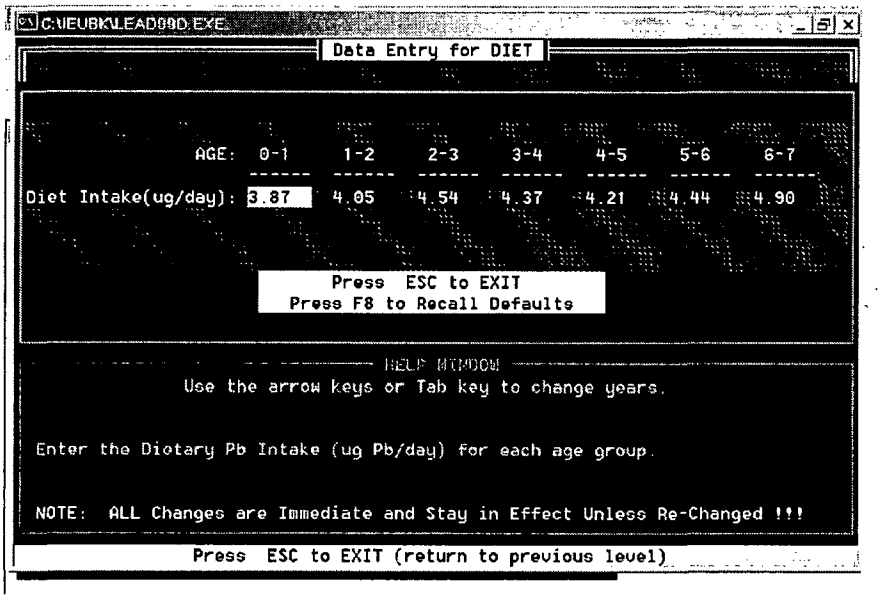
Sediment Intake: Average recreational visitors are thought to be exposed to sediments approximately 5 times/year while visiting the site. During each visit, children are assumed to ingest 25 mg of sediment. Based on a log-normal 95UCL lead concentration of 4,446 mg/kg in sediments, this is expected to result in an additional 1.5 ug/day of lead on a yearly basis. Therefore, in the combined residential/recreational scenario, a value of 1.5 ug/day was added to each year of childhood exposure. The following values were input into "other" sources in order to account for ingestion of lead in site sediments:

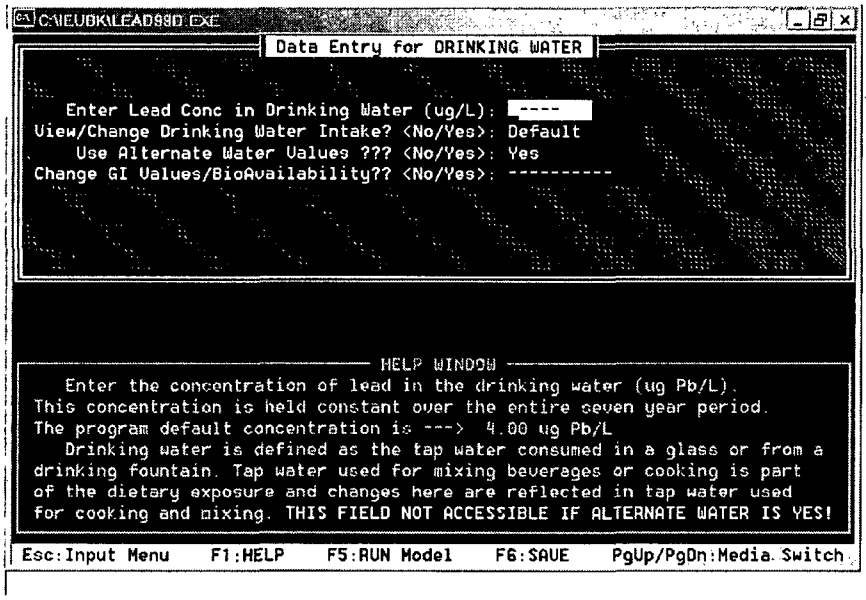
Age (years)	Other Intake (ug/day)
0-1	1.5
1-2	1.5
2-3	1.5
3-4	1.5
4-5	1.5
5-6	1.5
6-7	1.5

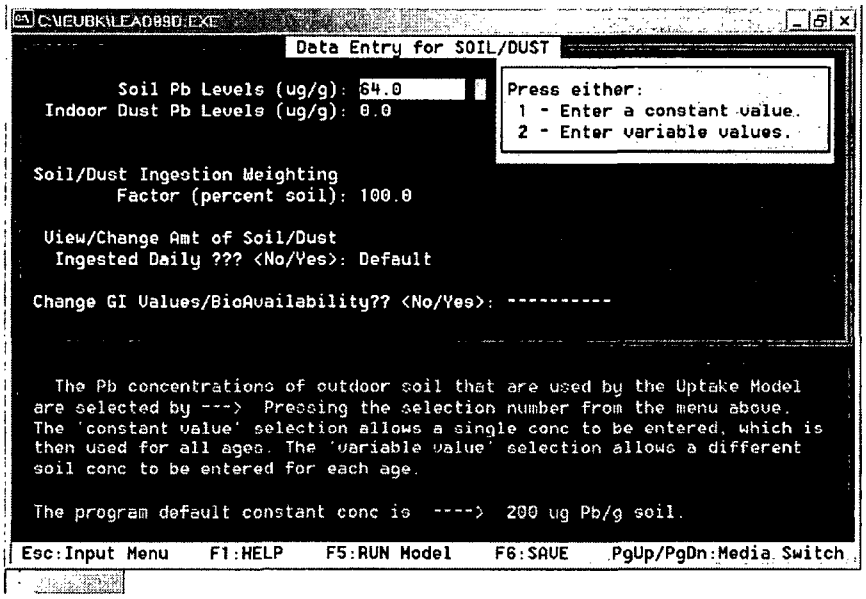
These values were obtained by multiplying the assumed intake of sediment (0.34 mg/day) by the average concentration of lead in site sediments (4,446 mg/kg) to obtain a lead intake of 1.5 ug/day.

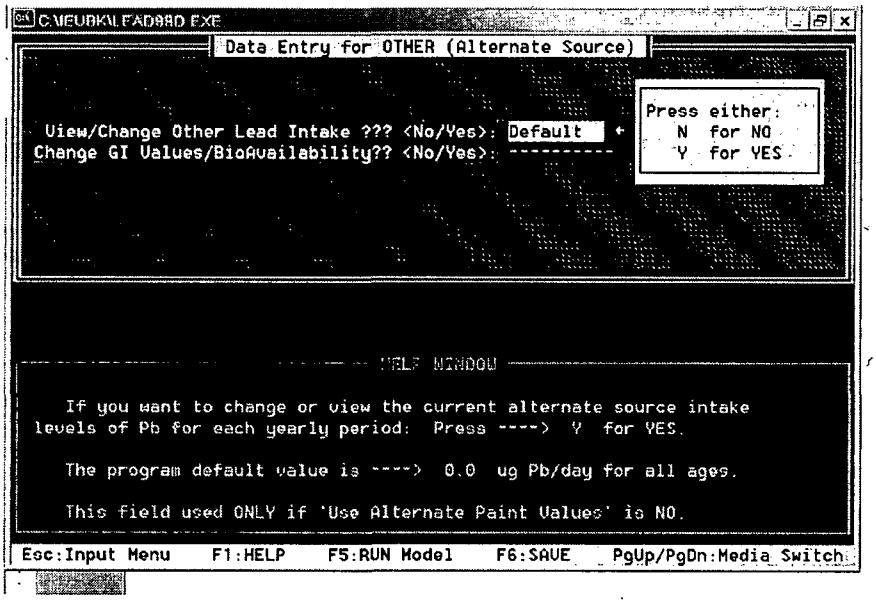
IEUBK INPUT PARAMETERS FOR CHILD EXPOSED VIA RESIDENTIAL EXPOSURE ONLY



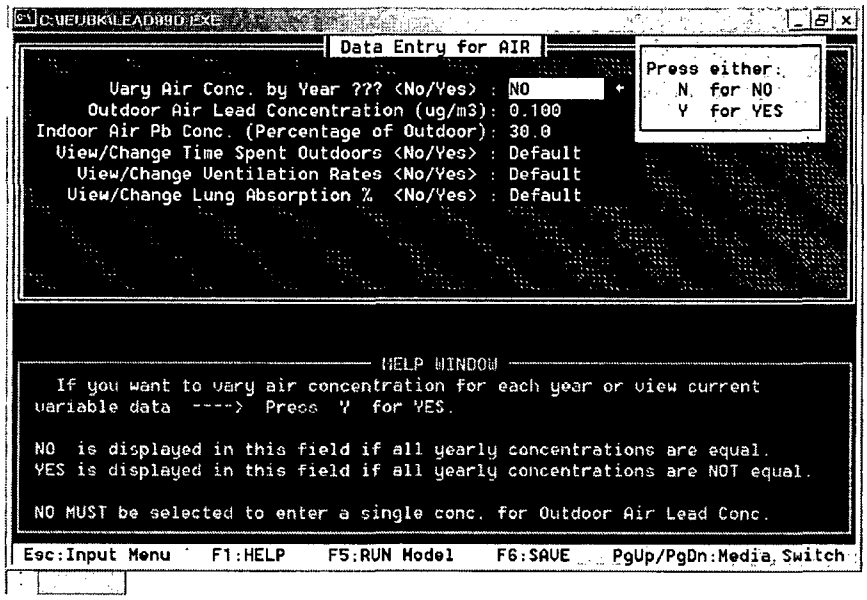


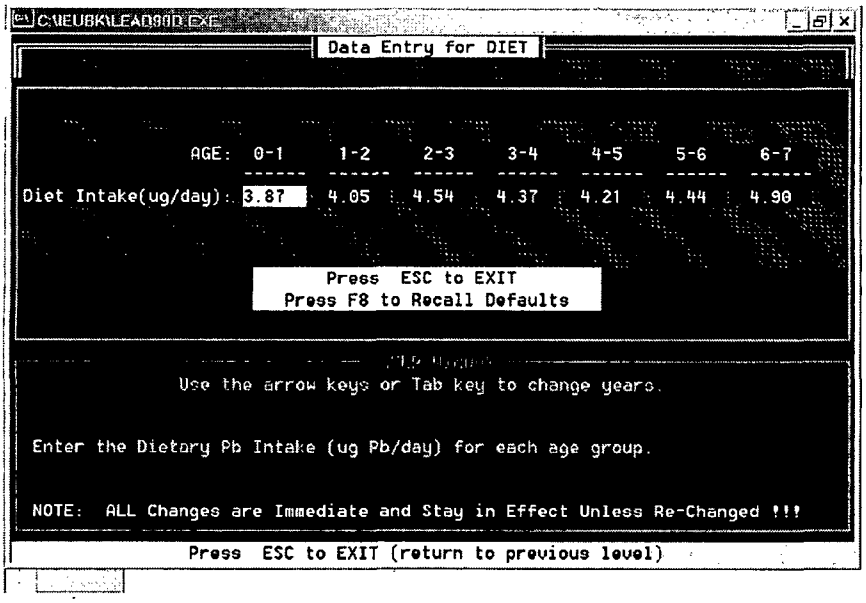

C:\IEUBK\LEAD98D.EXE
Data Entry for DRINKING WATER
Enter Lead Conc in Drinking Water (ug/L): ----
View/Change Drinking Water Intake? <No/Yes>: Default
Use Alternate Water Values ??? <No/Yes>: Yes
Change GI Values/BioAvailability?? <No/Yes>: ----------
HELP WINDOW
Enter the concentration of lead in the drinking water (ug Pb/L).
This concentration is held constant over the entire seven year period.
The program default concentration is ---> 4.00 ug Pb/L
Drinking water is defined as the tap water consumed in a glass or from a drinking fountain. Tap water used for mixing beverages or cooking is part of the dietary exposure and changes here are reflected in tap water used for cooking and mixing. THIS FIELD NOT ACCESSIBLE IF ALTERNATE WATER IS YES!
Esc:Input Menu F1:HELP F5:RUN Model F6:SAVE PgUp/PgDn:Media Switch

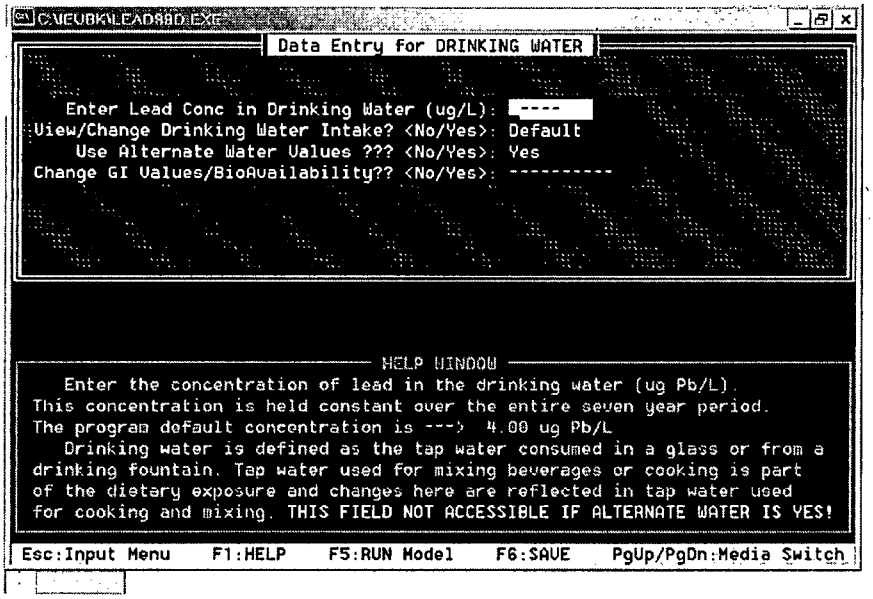

C:\IEUBK\LEAD98D.EXE
Data Entry for SOIL/DUST
Soil Pb Levels (ug/g): 64.0
Indoor Dust Pb Levels (ug/g): 0.0
Press either:
1 - Enter a constant value.
2 - Enter variable values.
Soil/Dust Ingestion Weighting Factor (percent soil): 100.0
View/Change Amt of Soil/Dust Ingested Daily ??? <No/Yes>: Default
Change GI Values/BioAvailability?? <No/Yes>: ----------
The Pb concentrations of outdoor soil that are used by the Uptake Model are selected by ---> Pressing the selection number from the menu above. The 'constant value' selection allows a single conc to be entered, which is then used for all ages. The 'variable value' selection allows a different soil conc to be entered for each age.
The program default constant conc is ----> 200 ug Pb/g soil.
Esc:Input Menu F1:HELP F5:RUN Model F6:SAVE PgUp/PgDn:Media Switch

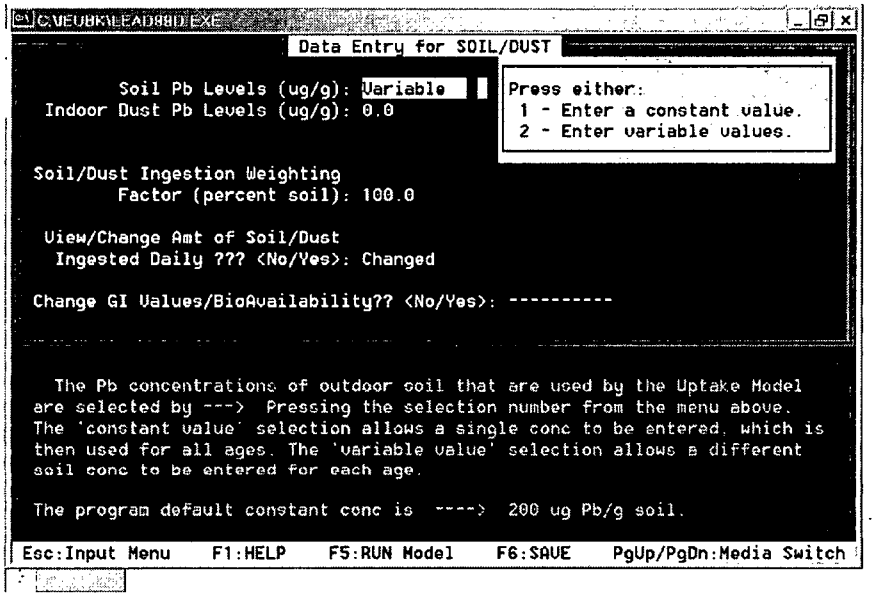

C:\IEUBK\LEAD98D.EXE
Data Entry for OTHER (Alternate Source)
View/Change Other Lead Intake ??? <No/Yes>: Default
Change GI Values/BioAvailability?? <No/Yes>: ----------
Press either:
N for NO
Y for YES
HELP WINDOW
If you want to change or view the current alternate source intake levels of Pb for each yearly period: Press ----> Y for YES.
The program default value is ----> 0.0 ug Pb/day for all ages.
This field used ONLY if 'Use Alternate Paint Values' is NO.
Esc:Input Menu
F1:HELP
F5:RUN Model
F6:SAVE
PgUp/PgDn:Media Switch

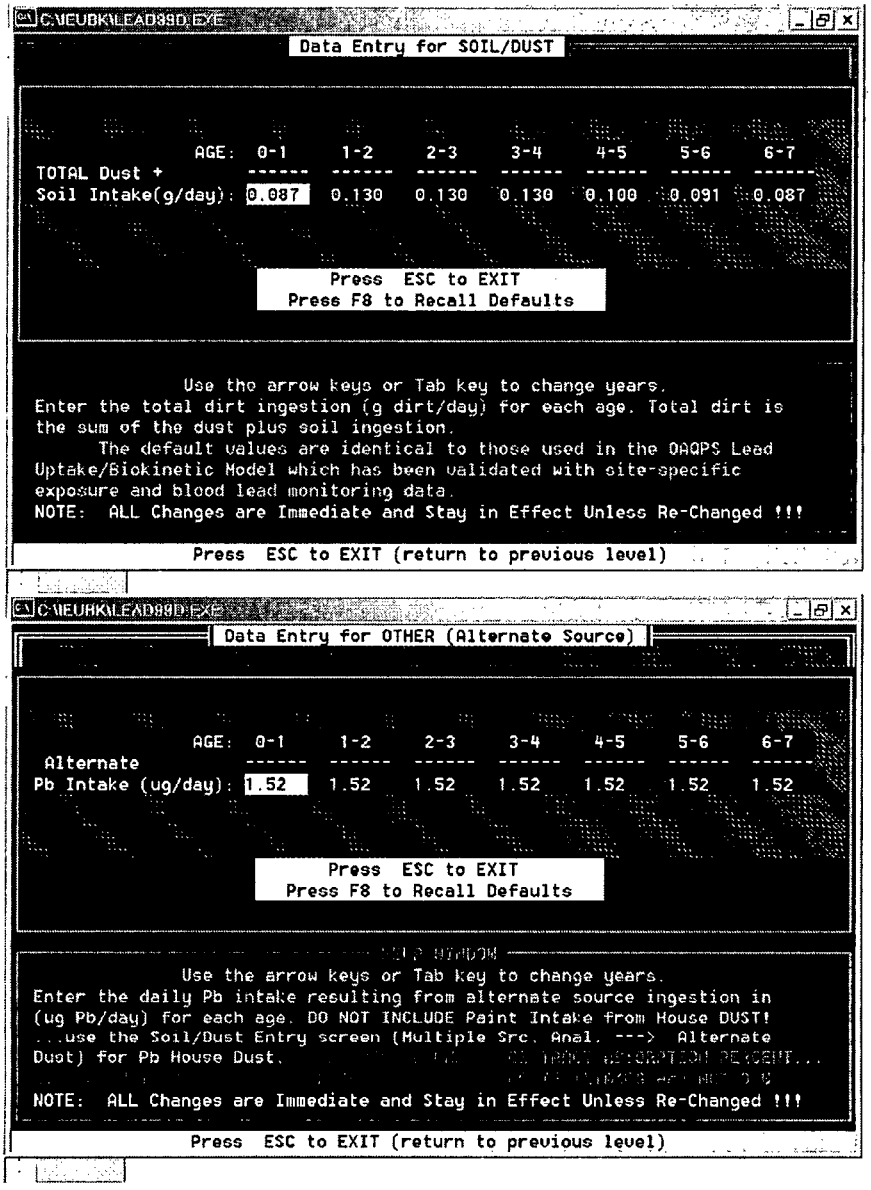
IEUBK INPUT PARAMETERS FOR CHILD EXPOSED VIA RESIDENTIAL AND RECREATIONAL EXPOSURE






C:\EUBK\LEAD98D.EXE
Data Entry for DRINKING WATER
Enter Lead Conc in Drinking Water (ug/L): ----
View/Change Drinking Water Intake? <No/Yes>: Default
Use Alternate Water Values ??? <No/Yes>: Yes
Change GI Values/BioAvailability?? <No/Yes>: ----------
HELP WINDOW
Enter the concentration of lead in the drinking water (ug Pb/L).
This concentration is held constant over the entire seven year period.
The program default concentration is ---> 4.00 ug Pb/L
Drinking water is defined as the tap water consumed in a glass or from a drinking fountain. Tap water used for mixing beverages or cooking is part of the dietary exposure and changes here are reflected in tap water used for cooking and mixing. THIS FIELD NOT ACCESSIBLE IF ALTERNATE WATER IS YES!
Esc:Input Menu F1:HELP F5:RUN Model F6:SAVE PgUp/PgDn:Media Switch


C:\EUBK\LEAD98D.EXE
Data Entry for SOIL/DUST
Soil Pb Levels (ug/g): Variable
Indoor Dust Pb Levels (ug/g): 0.0
Press either:
1 - Enter a constant value.
2 - Enter variable values.
Soil/Dust Ingestion Weighting Factor (percent soil): 100.0
View/Change Amt of Soil/Dust Ingested Daily ??? <No/Yes>: Changed
Change GI Values/BioAvailability?? <No/Yes>: ----------
The Pb concentrations of outdoor soil that are used by the Uptake Model are selected by ---> Pressing the selection number from the menu above. The 'constant value' selection allows a single conc to be entered, which is then used for all ages. The 'variable value' selection allows a different soil conc to be entered for each age.
The program default constant conc is ----> 200 ug Pb/g soil.
Esc:Input Menu F1:HELP F5:RUN Model F6:SAVE PgUp/PgDn:Media Switch


C:\EUBK\LEAD98D.EXE
Data Entry for SOIL/DUST
AGE: 0-1 1-2 2-3 3-4 4-5 5-6 6-7
TOTAL Dust + Soil Intake(g/day): 0.087 0.130 0.130 0.130 0.100 0.091 0.087
Press ESC to EXIT
Press F8 to Recall Defaults
Use the arrow keys or Tab key to change years.
Enter the total dirt ingestion (g dirt/day) for each age. Total dirt is the sum of the dust plus soil ingestion.
The default values are identical to those used in the OAQPS Lead Uptake/Biokinetic Model which has been validated with site-specific exposure and blood lead monitoring data.
NOTE: ALL Changes are Immediate and Stay in Effect Unless Re-Changed !!!
Press ESC to EXIT (return to previous level)
C:\EUBK\LEAD98D.EXE
Data Entry for OTHER (Alternate Source)
AGE: 0-1 1-2 2-3 3-4 4-5 5-6 6-7
Alternate Pb Intake (ug/day): 1.52 1.52 1.52 1.52 1.52 1.52 1.52
Press ESC to EXIT
Press F8 to Recall Defaults
Use the arrow keys or Tab key to change years.
Enter the daily Pb intake resulting from alternate source ingestion in (ug Pb/day) for each age. DO NOT INCLUDE Paint Intake from House DUST!
...use the Soil/Dust Entry screen (Multiple Src. Anal. ---> Alternate Dust) for Pb House Dust.
NOTE: ALL Changes are Immediate and Stay in Effect Unless Re-Changed !!!
Press ESC to EXIT (return to previous level)